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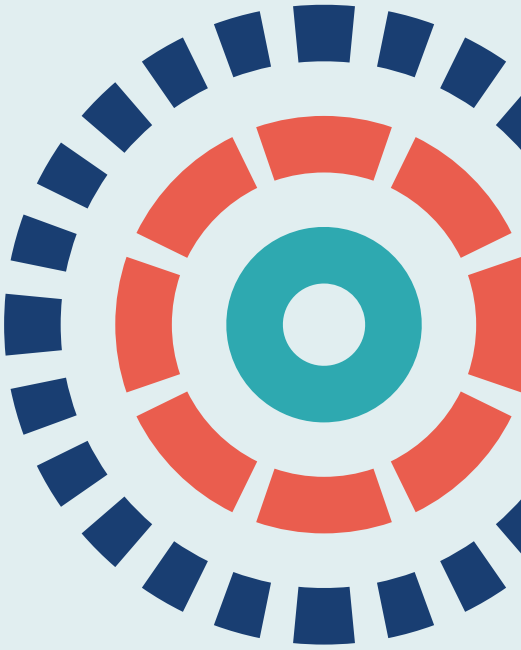

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Active design of built environments for increasing levels of physical activity in adults: the ENABLE London natural experiment study

Christopher G Owen,[1*] Elizabeth S Limb,[1] Claire M Nightingale,[1] Alicja R Rudnicka,[1] Bina Ram,[1] Aparna Shankar,[1] Steven Cummins,[2] Daniel Lewis,[2] Christelle Clary,[2] Ashley R Cooper,[3,4] Angie S Page,[3,4] Duncan Procter,[3,4] Anne Ellaway,[5] Billie Giles-Corti,[6] Peter H Whincup[1] and Derek G Cook[1]

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Abstract

Active design of built environments for increasing levels of physical activity in adults: the ENABLE London natural experiment study

Christopher G Owen,[1*] Elizabeth S Limb,[1] Claire M Nightingale,[1] Alicja R Rudnicka,[1] Bina Ram,[1] Aparna Shankar,[1] Steven Cummins,[2] Daniel Lewis,[2] Christelle Clary,[2] Ashley R Cooper,[3,4] Angie S Page,[3,4] Duncan Procter,[3,4] Anne Ellaway,[5] Billie Giles-Corti,[6] Peter H Whincup[1] and Derek G Cook[1]

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Background: Low physical activity is widespread and poses a serious public health challenge both globally and in the UK. The need to increase population levels of physical activity is recognised in current health policy recommendations. There is considerable interest in whether or not the built environment influences health behaviours, particularly physical activity levels, but longitudinal evidence is limited.

Objectives: The effect of moving into East Village (the former London 2012 Olympic and Paralympic Games Athletes' Village, repurposed on active design principles) on the levels of physical activity and adiposity, as well as other health-related and well-being outcomes among adults, was examined.

Design: The Examining Neighbourhood Activities in Built Environments in London (ENABLE London) study was a longitudinal cohort study based on a natural experiment.

Setting: East Village, London, UK.

Participants: A cohort of 1278 adults (aged ≥ 16 years) and 219 children seeking to move into social, intermediate and market-rent East Village accommodation were recruited in 2013–15 and followed up after 2 years.

Intervention: The East Village neighbourhood, the former London 2012 Olympic and Paralympic Games Athletes' Village, is a purpose-built, mixed-use residential development specifically designed to encourage healthy active living by improving walkability and access to public transport.

Main outcome measure: Change in objectively measured daily steps from baseline to follow-up.

Methods: Change in environmental exposures associated with physical activity was assessed using Geographic Information System-derived measures. Individual objective measures of physical activity using accelerometry, body mass index and bioelectrical impedance (per cent of fat mass) were obtained, as were perceptions of change in crime and quality of the built environment. We examined changes in levels of physical activity and adiposity using multilevel models adjusting for sex, age group, ethnic group, housing sector (fixed effects) and baseline household (random effect), comparing the change in those who moved to East Village (intervention group) with the change in those who did not move to East Village (control group). Effects of housing sector (i.e. social, intermediate/affordable, market-rent) as an effect modifier were also examined. Qualitative work was carried out to provide contextual information about the perceived effects of moving to East Village.

Results: A total of 877 adults (69%) were followed up after 2 years (mean 24 months, range 19–34 months, postponed from 1 year owing to the delayed opening of East Village), of whom 50% had moved to East Village; insufficient numbers of children moved to East Village to be considered further. In adults, moving to East Village was associated with only a small, non-significant, increase in mean daily steps (154 steps, 95% confidence interval −231 to 539 steps), more so in the intermediate sector (433 steps, 95% confidence interval −175 to 1042 steps) than in the social and market-rent sectors (although differences between housing sectors were not statistically significant), despite sizeable improvements in walkability, access to public transport and neighbourhood perceptions of crime and quality of the built environment. There were no appreciable effects on time spent in moderate to vigorous physical activity or sedentary time, body mass index or percentage fat mass, either overall or by housing sector. Qualitative findings indicated that, although participants enjoyed their new homes, certain design features might actually serve to reduce levels of activity.

Conclusions: Despite strong evidence of large positive changes in neighbourhood perceptions and walkability, there was only weak evidence that moving to East Village was associated with increased physical activity. There was no evidence of an effect on markers of adiposity. Hence, improving the physical activity environment on its own may not be sufficient to increase population physical activity or other health behaviours.

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Supplementary material can be found on the NIHR Journals Library report page (https://doi.org/10.3310/phr08120).

Supplementary material has been provided by the authors to support the report and any files provided at submission will have been seen by peer reviewers, but not extensively reviewed. Any supplementary material provided at a later stage in the process may not have been peer reviewed.

List of abbreviations

BMI	body mass index
CI	confidence interval
CMD	common mental disorder
CPM	counts per minute
ENABLE London	Examining Neighbourhood Activities in Built Living Environments in London
GiGL	Greenspace Information for Greater London
GIS	geographic information system
GPS	Global Positioning System
IPAQ	International Physical Activity Questionnaire
IQR	interquartile range
LLI	limiting longstanding illness
LSHTM	London School of Hygiene & Tropical Medicine
MVPA	moderate to vigorous physical activity
NS-SEC	National Statistics Socioeconomic Classification
OR	odds ratio
OS	Ordnance Survey
PTAL	public transport accessibility level
RESIDE	RESIDential Environment
SD	standard deviation
STAMP-2	Sedentary Time and Metabolic Health in People with type-2 diabetes mellitus
TfL	Transport for London

Plain English summary

What was the problem?

Physical activity levels are too low, and population-based strategies to improve physical activity levels have had modest effects, at best. However, small improvements across communities could have significant effects on health outcomes at a population level. Changes in the neighbourhood built environment may offer an attractive way to increase physical activity levels, given their potential reach.

What did we do?

East Village, the former London 2012 Olympic and Paralympic Games Athletes' Village, was repurposed to provide social, affordable (intermediate) and market-rent housing with high levels of walkability and close proximity to improved public transport. The Examining Neighbourhood Activities in Built Living Environments in London (ENABLE London) study was a natural experiment that aimed to examine whether or not objectively measured physical activity levels, body fat and mental health/well-being show sustained change after 2 years in individuals relocating to East Village compared with a control population living outside East Village throughout.

What did we find?

East Village resulted in a marked improvement in objective measures of the built environment (including improved walkability and access to public transport) and more positive perceptions of lower crime (i.e. less vandalism, feeling safer to walk in the neighbourhood and less of a presence of threatening groups) and quality of the built environment among residents (particularly among those moving to East Village social housing). Despite these sizeable improvements, there were only modest increases in physical activity levels (particularly in the number of daily steps) and few differences in higher levels of physical activity (i.e. moderate to vigorous physical activity), sedentary time, measures of body fatness and other health-related outcomes.

What does this mean?

This study, using a robust design, showed modest improvements in physical activity and other health-related behaviours associated with moving to accommodation designed for active living, suggesting that improving the built environment alone is insufficient to increase population levels of physical activity. Further work is needed to examine how changes in the built environment can lead to improved health behaviours, such as physical activity.

Scientific summary

Background

Although the built environment may be an important influence on physical activity patterns, particularly on the uptake of walking and cycling to everyday destinations, there is a dearth of longitudinal evidence. The East Village development offered a unique opportunity for a longitudinal natural experiment to assess the impact of relocation to a purpose-designed walkable urban built environment on physical activity patterns. The transformation of East Village into social, affordable/intermediate and market-rent housing was carried out in a rapid timescale (with the first residents scheduled for occupancy in 2013, after the London 2012 Olympic and Paralympic Games) and was specifically conceived with active design features (including improved access to public transport, secure bicycle spaces allocated for every home and restrictions on car ownership). The development is further enhanced by regeneration of the surrounding area (particularly the extension of walkways and cycle paths to the Lee Valley and connection to the London Cycle Network). The accommodation is for those from widely differing socioeconomic backgrounds, allowing social inequalities in use of the area to be gauged. The rapid transformation allowed change in physical activity levels (as well as in other health behaviours/outcomes) to be compared between residents who relocated to East Village and control participants who remained in their original housing or moved elsewhere over a defined period. This is a unique opportunity as it (1) represents a natural experiment of people from diverse social backgrounds relocating into a new walkable neighbourhood and (2) reduces the effects of time-dependent factors that may override the potential effects of change in the built environment, which would be a factor in most new housing developments that often take much longer to complete.

Aims

The primary aims of the Examining Neighbourhood Activities in Built Living Environments in London (ENABLE London) study were to address the following research questions:

1. Do those living in social, intermediate and market-rent housing in East Village show a sustained change in their physical activity levels compared with their levels before moving and compared with the physical activity change among those who did not move into East Village?
2. Are any changes in physical activity observed among those who moved to East Village attributable to differences in mode of travel (particularly use of public transport, levels of walking and cycling) and/or use of the local built environment (e.g. open spaces, cycle paths, pedestrian walkways, recreational or green space, sporting venues)? In addition, are any changes modified by housing tenure, socioeconomic position, housing type or use and perceptions of the local environment and its specific features?

In addition, the ENABLE London study sought to answer the following secondary research questions:

3. Are there any changes in adiposity levels among those living in East Village and do these show a sustained change from levels before moving into East Village, in comparison with changes observed among those who did not move to East Village over the same time period?
4. Does moving to East Village improve levels of mental health (depression and anxiety) and well-being (including levels of life satisfaction, happiness and feelings of worthiness) compared with remaining outside East Village throughout?

Another important issue for the ENABLE London study was to investigate change in the built environment associated with the East Village development (i.e. the primary exposure variable), without which the change in the outcome variables would not be expected. Hence, we also sought to:

5. Quantify change in objective measures of the built environment (including neighbourhood walkability, land use mix, proximity to parks and public transport accessibility) comparing the areas in which residents were living before and after moving to East Village with control areas.

Although a primary goal of the study was to examine families, it was not possible to examine change in children's physical activity levels because the number of children recruited was small (see *Overall research design*).

Methods

Overall research design

We carried out a longitudinal study to evaluate the natural experiment provided by the opening of East Village. The length of follow-up was extended from the initially proposed 1 year to 2 years owing to delays in the alterations of East Village, which resulted in a staggered release of different tenured accommodation ready for occupancy. This was an unforeseen delay that was out of the control of the researchers. The original study design planned to collect baseline measures during 2013, prior to the scheduled completion of East Village in the summer of 2013, with repeat measures in 2014. However, East Village residents did not start to move in until 2014, with the social sector residents moving in before the development was complete. Intermediate and market-rent residents moved in when the development was more fully open, with unrestricted access to the immediate and surrounding area. Follow-up in the control group (those who were seeking to move but did not) also had to be delayed to ensure that interviews were carried out during the same period as interviews with the East Village group (i.e. those who moved to East Village) to provide controlled comparisons and to avoid any potential time-dependent effects.

Participant recruitment and follow-up

A cohort of adults seeking to move into three different housing tenures in East Village were recruited between January 2013 and January 2016. East Thames Group housing association was responsible for social housing in East Village, Triathlon Homes for the intermediate accommodation (affordable market-rent/shared-ownership/shared-equity) and Get Living London for market-rent (private rent). Recruitment was carried out by the East Thames Group for the social sector and ENABLE London researchers for the remainder. Of the 1819 households invited, 1006 (55%) agreed to take part, and 1278 adults and 219 children from these households were examined at baseline; the children were recruited mainly from the social housing sector. We expected to recruit similar numbers of adults and children, and the small number of children was unforeseen. East Village accommodation mainly consists of houses of three or four bedrooms but it did not attract the number of families that were expected. Unfortunately, the number of children was insufficient and underpowered to examine change in physical activity, as well as in other health outcomes; hence, only adults were considered further. Participants were grouped into type of housing tenure being sought, which was largely based on level of income. Participation rates were slightly lower among those seeking social rented housing (52%) than among those seeking intermediate housing (57%) and market-rent (58%). The 2-year follow-up of the cohort began in February 2015 and was completed in October 2017. In total, 877 adults (follow-up rate 69%) from 710 households (71%) were re-examined; 440 adults (50%) were living in East Village and 437 adults (50%) were living at their baseline address or had moved elsewhere (control group). This was remarkably similar to what we initially proposed (70% and 50%, respectively), although there was some imbalance between East Village and control groups among the different housing sectors.

Baseline and follow-up examinations

Baseline and follow-up examinations were carried out in the participants' homes. Adult self-complete computer-assisted personal interviewing collected information on sociodemographic data, occupation, mental health and well-being, travel to and from work, physical activity and neighbourhood perceptions. Trained researchers took measures of height, weight and bioimpedance (to obtain a more direct measure of body fat). Participants were invited to wear an accelerometer (ActiGraph GT3X+; ActiGraph LLC, Pensacola, FL, USA) for objective assessment of physical activity and a Global Positioning System monitor (BT-1000XT; QStarz International Co, Ltd, Taipei, Taiwan) to investigate their movements, on an elasticated belt around the waist, for 7 consecutive days (removing devices for sleep, swimming and bathing), and were asked to return the instruments to the research team by post in a prepaid postal envelope at the end of the measurement period.

Results

Participant characteristics at baseline and follow-up

Participants recruited from the social housing sector were older (mean age 31 years vs. 29 years for other housing tenures), more often female (73%), mainly from ethnic minority backgrounds (82% non-white) and living in larger households (i.e. 58% with households of four or more people, which included children) than intermediate and market-rent participants, who were largely of white ethnicity (69%), with similar numbers of males and females (46% female), and mostly (39%) living in two-person adult households. Only half (49%) of social housing participants were employed, compared with approximately 90% of the intermediate and market-rent participants. Despite these housing sector differences in baseline characteristics, there were no appreciable differences in sociodemographic factors (i.e. in age, sex or ethnic group) between those followed up and those not followed up, although those followed up had a slightly higher National Statistics Socioeconomic Classification socioeconomic status and recorded more sedentary time at baseline than those who were not followed up.

Physical activity and adiposity

At baseline, objective measures of physical activity showed lower levels of activity among those in social housing, with fewer daily steps (8298 steps vs. 9390 steps for other housing tenures) and less time spent in higher levels of activity (i.e. time spent in moderate to vigorous physical activity, 54 minutes per day vs. 63 minutes per day for other housing tenures). Measures of body size showed higher levels of adiposity among those in the social housing sector (median body mass index 26 kg/m^2; median fat mass 18 kg) than among those in other housing sectors, with similar levels among those seeking intermediate and market-rent accommodation (median body mass index 24 kg/m^2; median fat mass 15 kg). At follow-up, a modest increase in the number of daily steps was associated with moving to East Village, with a 154-step (95% confidence interval −231 to 539 steps) increase overall and a larger (433 steps, 95% confidence interval −175 to 1042 steps) difference among the intermediate housing sector than among those who remained outside East Village throughout. However, none of these differences was statistically significant. There were no appreciable effects of moving to East Village on other physical activity outcomes (including overall activity counts, time spent in moderate to vigorous physical activity and sedentary time) and measures of adiposity (including body mass index and percentage fat mass).

Travel mode

Using a novel automated approach of identifying mode of travel from the combined accelerometry and Global Positioning System data, most of the cohort at baseline (75%) used public transport to travel to or from their place of work or study and half (50%) participated in some active travel (i.e. walking, cycling or jogging). There were marked differences by housing sector; social housing participants were less likely to walk, cycle or jog, recorded less time travelling by train and underground and were more likely to use private transport (e.g. travel by car) than intermediate and market-rent housing participants, who showed similar travel patterns. At 2-year follow-up, there was no change in the time spent walking or cycling among those who moved to East Village compared with those living elsewhere, which was commensurate

with the primary finding of little overall change in physical activity levels. However, there was some suggestion that vehicle travel had decreased (by 8.3 minutes per day, 95% confidence interval 2.5 to 14.0 minutes per day) particularly in the intermediate sector (9.6 minutes per day, 95% confidence interval 2.2 to 16.9 minutes per day) and that underground travel had increased (by 3.9 minutes per day, 95% confidence interval 1.2 to 6.5 minutes per day), more so in the market-rent sector (11.5 minutes per day, 95% confidence interval 4.4 to 18.6 minutes per day). Although underground use also appeared to increase among the social sector (by 4.0 minutes per day, 95% confidence interval −0.1 to 8.1 minutes per day), time spent walking marginally decreased, although not significantly (by 1.8 minutes per day, 95% confidence interval −4.8 to 8.4 minutes per day).

Mental health and well-being

Baseline levels of self-reported mental health and well-being showed that 14% of the whole cohort reported depression, 31% reported anxiety and one-quarter reported poor well-being. Participants from the social housing sector reported poorer mental health and well-being than those seeking intermediate and market-rent accommodation. At 2-year follow-up, there were no consistent effects associated with moving to East Village on depression and anxiety in comparison with the control group, although there was some evidence to suggest that there were improvements in well-being, with improved life satisfaction among the intermediate sector in particular [improvement in score on a scale of 0 (low) to 10 (high) of 0.3, 95% confidence interval 0.0 to 0.6].

The built environment and neighbourhood perceptions

There were sizeable improvements in objective measures of the built environment associated with moving to East Village. Compared with baseline data, participants in East Village lived closer to their nearest park (by 531 m, 95% confidence interval 488 to 574 m), had better access to public transport (change in accessibility score 1.6 units, 95% confidence interval 1.3 to 1.9 units) and lived in a more walkable area (change in walkability score of 2.4 units, 95% confidence interval 2.1 to 2.7 units). For baseline neighbourhood perceptions of crime-free neighbourhood and neighbourhood quality, perceptions of baseline residence were lower among the social housing sector than among other housing sectors; that is, the social housing sector perceived higher levels of crime and poorer neighbourhood quality at baseline than intermediate and market-rent sectors. However, at follow-up, marked improvements in neighbourhood perception scores were observed among those who moved to East Village, compared with those who did not move. These marked differences were observed both overall (change in crime-free neighbourhood score 3.36 units, 95% confidence interval 2.83 to 3.90 units; quality score 4.98 units, 95% confidence interval 4.48 to 5.48 units) and by housing sector. The largest improvement in perceptions of crime-free neighbourhood was among the social housing sector who moved into East Village (where the change in crime-free neighbourhood score was 3.95 units, 95% confidence interval 2.97 to 4.94 units).

Qualitative findings

Two separate pieces of qualitative analyses, based on a total of 30 ENABLE London participants, provided important contextual information about the perceived effects of moving to East Village, allowing consistency with measured effects in the cohort at large to be established as well as investigating factors that are difficult to measure quantitatively. Findings indicated that those who moved into East Village housing enjoyed their new homes and living in the area, which was perceived as attractive and safe. However, concerns over the high cost of living, restrictions on the playing times of children (particularly during summer months) and facilities for young people were raised (although this may have reflected the partial opening of East Village for some of the earlier interviews). Consistent with quantitative data, participants had generally more positive perceptions of their new environment than their old environment and recognised many features of the built environment that encouraged physical activity, particularly those that encouraged leisure-time activities. However, any effect of these more positive perceptions on physical activity may have been offset by changes in transport-related activity. The relatively sophisticated and accessible transport options in East Village may have reduced the walking required to access transport hubs. Further development of retail and

leisure-related space in East Village will continue to diversify the area and increase opportunities for social interactions, which could encourage physical activity and improve other health behaviours. However, any such changes might be affected by recent plans to create high-storey living space, leading to reduced recreational green space.

Conclusions

Cross-sectional evidence has suggested larger effects of the neighbourhood built environment on physical activity and other health-related outcomes than evidence from longitudinal studies. Very few studies have evaluated housing regeneration projects. The ENABLE London study provided a unique opportunity. At 2-year follow-up, moving to East Village, a neighbourhood designed for healthy active living that showed sizeable improvements in the built environment and neighbourhood perceptions, did not have consistent beneficial effects on objectively measured physical activity, adiposity, mental health or well-being, which are of public health importance. This study suggests that the built environment alone is insufficient to change physical activity behaviour.

Research recommendations

More evidence from similar studies is needed to confirm these findings, in particular high-quality evidence from longitudinal relocation studies that examine the effect of change in the built environment on changes in physical activity levels, focusing on potential movers as opposed to 'mover versus stayer' populations with different health behaviours to avoid potential biases. However, opportunities for large-scale relocation studies are rare, and the difficulties, time needed and costs make such studies challenging; alternative innovative population-based approaches (perhaps harnessing the latest developments in technologies) to evaluate the effect of housing regeneration projects on health will be needed to inform and evaluate future evidence-based housing policy.

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Chapter 1 Background to the ENABLE London study

Importance of physical inactivity

Physical inactivity is one of the leading causes of premature mortality, responsible for over 5 million deaths per year worldwide.[1] Low levels of physical activity are associated with numerous adverse health outcomes in adulthood, including coronary heart disease, stroke, type 2 diabetes mellitus and cancers.[2] The annual global health-care cost of physical inactivity has been estimated to be near $54B.[3] In the UK, physical activity levels are undesirably low, with over one-third of men and 40% of women not meeting physical activity recommendations of at least 150 minutes of moderate activity per week.[4] The important need to address this has resulted in initiatives to increase population levels of physical activity, which have become enshrined within public health policy.[5,6] Evidence suggests that levels of physical activity are lowest among those who are socioeconomically disadvantaged[7] and those who experience greater economic, access and health-related barriers to being physically active,[8] which potentially drives social inequalities. Socioeconomic status is also associated with differences in the types of physical activity observed; in particular, higher socioeconomic status is associated with more vigorous leisure-time physical activity.[9] Previous research has found variation in physical activity by day of the week, with studies showing lower levels of activity on Sundays than weekdays in young adults[10] and parents and their children.[11]

Housing tenure

There is emerging evidence, from UK-based studies[12,13] in particular, suggesting that housing tenure (owner vs. private renter vs. public sector renter) may be an important determinant of health. Among particular groups, including those who are economically inactive or unemployed, housing tenure might provide a better indication of socioeconomic status than measures based on occupation or income.[14] Indeed, in several studies housing tenure remained associated with health outcomes following adjustment for conventional measures of socioeconomic status, such as income or education.[12,15] A more nuanced approach is therefore required with respect to measures of socioeconomic status, and they should not be simply regarded as interchangeable.[13,16] Despite this, there has been limited research examining the direct effect of housing tenure on physical activity, and existing evidence is equivocal. Harrison *et al.*[17] found no association between housing tenure and meeting the recommended levels of physical activity among community-dwelling healthy adults in the north-east of England.[17] Similarly, housing tenure was not associated with self-reported energetic physical activity among older Australians.[18] Ogilvie *et al.*[19] found overall levels of physical activity to be higher in individuals living in social housing than in owner-occupiers.[19] The authors suggest that social housing tenure may capture occupational physical activity levels that are likely to be higher among those in social housing.[19] By contrast, living in private-rented accommodation was associated with a greater likelihood of taking up exercise over a 9-year period among men aged 18–49 years at baseline than living in local authority accommodation.[20]

The residential built environment

Housing tenure may affect health and health behaviours in part through characteristics of the home or the neighbourhood itself,[21,22] or through psychological factors such as self-efficacy or self-esteem.[23] Social housing estates, which are common in the UK, may be associated with specific cultures and norms, which in turn shape residents' behaviours.[12] Subjective characteristics of the neighbourhood

environment, such as higher perceived access to recreational facilities and shops in local proximity, have been shown to be associated with higher levels of physical activity.[24,25] Residents who perceive their neighbourhood more positively have been shown to have better mental health and are less likely to relocate.[26] Conversely, real and perceived crime has the potential to constrain residents' physical activity.[27] However, a recent systematic review suggested a lack of association between physical activity and perceptions of safety from crime; this highlights the need for high-quality evidence, including prospective studies and natural experiments,[28] to examine this issue further. In particular, high-quality evidence is needed to understand the potentially multifactorial influence of residential location on health and health behaviours, with effects that are likely to extend beyond simple measures of socioeconomic status.[28]

Dose–response meta-analyses suggest that even small increases in physical activity would confer significant health benefits, particularly for cardiovascular and diabetes mellitus-related outcomes.[2] Increasing physical activity levels, particularly among those living in more disadvantaged neighbourhoods, is an important public health priority. However, a wide range of community-wide interventions to increase population levels of physical activity, particularly those associated with change in the residential built environment, have failed to show consistently beneficial effects.[29] Moreover, where modest effects have been shown, there is very little evidence and persistence of effects is not routinely assessed.[29] Despite this, community-wide interventions related to the built environment remain attractive given their population reach.

Physical activity and the built environment

There is growing literature that investigates the influence of the built environment on physical activity levels.[30] It seems highly plausible that improved walkability and improved access to green space, public transport and recreational facilities would encourage increased physical activity.[31] However, evidence is heavily reliant on cross-sectional studies,[32] which are prone to selection bias, in which people who are living in less walkable neighbourhoods are often intrinsically different from those who are not. Such studies make it difficult to establish temporality or to infer causal effects.[33] Moreover, evidence has been mixed showing built environment-related associations with adiposity, but not with physical activity, which suggests that other health behaviours might be affected.[34,35] Longitudinal studies have sought to establish causal associations of physical activity and the built environment, but the number of studies are few and the systematic reviews of studies, to date, have found this evidence less convincing.[29,33,36] Specific methodological weaknesses have included (1) comparing movers with non-movers, who may be inherently different and have different reasons for moving or staying that govern their physical activity patterns,[33] and (2) often relying on self-reported physical activity, which is prone to measurement error and reporting bias,[37] and which could have an appreciable impact on the reporting of health outcomes at a population level.[38] There have been increasing calls for high-quality evidence, particularly natural experiments, to evaluate the effect of the built environment on health behaviours, specifically physical activity levels, in which the population effects of sizeable change in the built environment can be examined.[39–41] However, there have been limited opportunities to carry out such studies.

The ENABLE London study

The Examining Neighbourhood Activities in Built Living Environments in London (ENABLE London) study takes advantage of the natural experiment provided by the rapid change of brown-field land in the London Borough of Newham, UK, to create a novel built environment for public use and occupancy (namely 'East Village' E20, formerly the London 2012 Olympic and Paralympic Games Athletes' Village). The extensive features of East Village, which make this sizeable change in the built environment suitable for evaluation as an intervention, are outlined below.

The East Village 'intervention'

The planned intervention was the mixed-use development of the East Village residential neighbourhood incorporating commercial, retail, educational and transportation resources.

Specific activity-permissive features designed to encourage physical activity include improved access to open land and parkland, unrivalled transport links, and active travel options (including extensive walking and cycling paths), design features of the local environment (such as street furniture, provision and arrangement of pedestrianised space, public space aesthetics, secure bicycle parking) and the provision of new formal cycling and walking facilities in the Queen Elizabeth Olympic Park, such as the VeloPark, and cycle paths that extend into the Lee Valley and connect to the London Cycle Network.[42,43] A local school, Chobham Academy, is within walking distance and provides schooling for all 3- to 19-year-olds. Retail outlets were planned within easy walking distance for everyday use (creating plazas at ground level within dedicated areas of East Village).[42,43] Moreover, East Village is in close proximity to Westfield Stratford City – Europe's largest urban shopping centre. Restriction of resident car parking (where fewer than one-sixth of homes have a designated parking space) combined with improved public transport links is designed to encourage local residents to adopt active modes of transport.[42,43]

Accommodation and housing tenures in East Village

East Village consists of 2818 units of accommodation, of which 1379 are social and intermediate accommodation (including shared ownership, shared equity and affordable market-rent), and 1439 are for market rent (private rent). The housing development includes a mixture of one- to four-bedroom town houses and apartments designed for single occupancy through to family-sized accommodation. Details of the different housing types are given below:

1. Social housing – approximately 675 units were available to those on the social housing register. The social housing sector is managed by East Thames Group and Triathlon Homes housing associations.
2. Intermediate accommodation – owned by Triathlon Homes (in association with the East Thames Group) with a total of 704 units (a mix of 79 shared ownership units, 269 shared equity units and 356 affordable market-rent units).
3. Market-rent accommodation – 1439 units owned by Get Living London for private rent.

Main research questions

The ENABLE London study sought to address the following primary research question: do those living in social, intermediate and market-rent accommodation in East Village show a sustained change in their physical activity levels, compared with their levels before moving into the Village, and compared with physical activity change among those who did not move into East Village?

Specific objectives of the study were to examine:

1. Whether or not any increase in physical activity observed among those living in East Village is directly attributable to the use of their local built environment and, if so, which facilities (e.g. open spaces, cycle paths, pedestrian walkways, recreational or green space, sporting venues) are important.
2. Whether or not changes in physical activity patterns in those living in East Village are modified by other factors, including age, sex, ethnicity, proximity to facilities, associated with living in East Village, housing tenure (as a marker of socioeconomic status) and employment status.

3. Whether or not adiposity levels among those living in East Village show a change from levels before moving into East Village, compared with any changes observed among those who did not move to East Village over the same period.
4. If changes in adiposity levels were observed, whether or not, and to what extent, changes in adiposity over the study period reflect changes in physical activity.

Secondary research questions included:

5. Does moving to East Village improve levels of mental health (depression and anxiety) and well-being, compared with those who did not move?
6. Does moving to East Village improve measures of the built environment and neighbourhood perceptions before and after moving, compared with those who remained outside East Village throughout?

This report

This report presents an original detailed description and summary of a large body of research, some of which has been published, submitted, or is being prepared for publication in other open-access academic journals. Further details of methods and findings presented in this report can be found in these publications, which are (1) cited in the report, (2) listed in *Publications* and (3) available on the study website (www.enable.sgul.ac.uk). We will continue to keep the study website updated with further publications emanating from the study.

Chapter 2 ENABLE London study methodology

Introduction

This chapter provides a description of the methods used in the ENABLE London study, providing an overview of the research design, participant recruitment and data collection. Key exposure and outcome variables collected during the study are outlined, along with a summary of the quantitative data analysis methods used. Derived variables and detailed analytic approaches used for different aspects of the study are described in each chapter accordingly.

Overall research design

The main aim of the study was to investigate the effect of a major change in the residential built environment, triggered by moving to East Village, an area purposefully planned on active design principles and on the physical activity levels of residents, in particular the levels of walking and cycling. There was also a broader set of research questions that this study sought to examine; importantly, examining change in the objective measures of the built environment associated with moving to East Village, in addition to neighbourhood perceptions of the area, to confirm that the development had the desired effect. Without being able to demonstrate change in the built environment (i.e. the primary exposure), change in health-related outcomes attributable to the built environment could not be expected. Other outcomes included change in travel mode and other health behaviours, including mental health and well-being. The study was originally conceived as a longitudinal study of adults seeking to move into the three housing tenures in East Village, with assessments taking place prior to and after the move. Within the cohort would be a control population: those who were seeking to move but did not move to East Village. The quantitative methods implemented in this study were supported by qualitative methods on a small sample of the cohort to further understand drivers and perceptions of moving to East Village and the potential effects on travel behaviours.

The East Village development was scheduled for occupancy in the summer of 2013. The original research design envisaged baseline measures to be taken from late 2012 to early 2013, and follow-up to be taken 1 year later from late 2013 to early 2014. However, delays to the opening of East Village led to the postponement of advertising the accommodation for occupancy and staggered release of accommodation by housing type, with the first residents of East Village not moving in until 2014. The research design of the study was therefore adapted to accommodate the delays to the opening of East Village and the staggered release of accommodation. With the delays in finalising the development and staged release of accommodation, coupled with the scientific need for 2-year as opposed to 1-year follow-up,[44] recruitment and baseline assessments of participants took place from 2013 to 2015, with a 2-year follow-up from 2015 to 2017.

Ethics considerations

Ethics approval for the study was provided by City Road and Hampstead Review Board (Research Ethics Committee reference number 12LO1031).

Study population

The inclusion criteria of the ENABLE London study were families residing in Greater London (largely from East London and the London Borough of Newham) who were seeking to move into social, intermediate and market-rent accommodation in East Village. Participants who moved to East Village at follow-up were directly exposed to the new social and built environment, and its active design features. Participants who were seeking to move to East Village but remained in their place of origin (largely from East London) or moved elsewhere formed the control group. Applicants registering an interest or applying to move into East Village were invited to take part in the study (including at least one adult and one child aged ≥ 8 years to allow accelerometer assessment); a maximum of four family members per household were included. Although the study was aimed at families (i.e. parents and children), working-aged adult-only households were also invited. Households with disabled family members were invited to the study when appropriate, although the primary focus of the study was able-bodied family members. Non-English-speaking families were also approached, using interpreters when applicable.

Socioeconomic position

The inclusion of occupants seeking social, intermediate and market-rent accommodation in East Village (largely based on level of income) allowed inclusion of people from widely different social and ethnic origins, representative of the diverse East London population. This allowed sociodemographic differences in the use of the local area and potential effects on health outcomes to be gauged,[5,45] particularly among individuals and households of lower socioeconomic status, who potentially have the most to gain from improvements in the residential built environment.[46]

Recruitment

Participants were recruited through the East Thames Group Housing Association (responsible for social housing tenants), Triathlon Homes (intermediate housing: affordable market-rent/shared ownership/shared equity) and Get Living London (market-rent). Prospective tenants went through a rigorous financial process to determine eligibility for accommodation. Those applying to move into East Village social housing were provided with information about the study and invited to take part by East Thames Group representatives directly, whereas the ENABLE London team (in association with Triathlon Homes and Get Living London) invited those from intermediate and market-rent housing sectors.

Data collection

Baseline and 2-year follow-up of study participants was carried out at the participants' home (or at a location convenient to the participant). Data items collected in the ENABLE London study at baseline and follow-up are listed in *Box 1* and summarised below.

Physical activity level/pattern and location

Objectively measured physical activity (daily steps) was the primary outcome and was assessed over a consecutive 7-day period using hip-mounted ActiGraph GT3X+ accelerometers, combined with an assessment of physical activity location using Global Positioning System (GPS) travel recorders (BT-1000XT). Accelerometers provided daily measures of steps and different intensities of activity, including moderate to vigorous physical activity (MVPA) (both overall and in 10-minute bouts, in accordance with UK physical activity recommendations, although levels in bouts were too low to be usefully used in analyses).[5]

BOX 1 Summary of data items collected at baseline and 2-year follow-up of the ENABLE London study

Physical activity and location data:

- ActiGraph GT3X+ accelerometer (ActiGraph LLC, Pensacola, FL, USA) worn over a consecutive 7-day period.
- QStarz BT-1000XT GPS travel recorder (QStarz International Co, Ltd, Taipei, Taiwan) worn for 1 week.
- Ordnance Survey AddressBase® Premium versions 2015 and 2017 (Ordnance Survey, Southampton, UK) mapping of place of residence at baseline and 2-year follow-up to provide measures of land use mix, street connectivity, residential density, walkability and connectivity indices (see www.ordnancesurvey.co.uk/business-government/products/addressbase-premium; accessed 16 September 2019).

Anthropometry:

- Height measured to the last complete millimetre (Leicester Stadiometer; Seca, Birmingham, UK).
- Weight measured to the last complete 0.1 kg using an electronic digital scale, and fat mass (kg), fat-free mass (kg) and muscle mass (kg) measured by leg-to-leg bioimpedance (Tanita SC-240 Body Composition Analyser; Tanita Inc, Tokyo, Japan).
- Body mass index calculated as weight/height squared in kg/m^2.

Questionnaire data:

- Demographics, including date of birth, gender and ethnicity, of the participant.
- Number of people living in the household, relationships, type of accommodation, household features (including lifts, stairs, garden), type of tenure, duration at current property, vehicles owned and dog ownership.
- Qualifications, employment status, and job title of adult participants (based on Census 2011 questions).[45]
- Method of travel to work/place of study and daily commuting times.
- Household income as either weekly or monthly amounts (based on National Evaluation of Sure Start income questions).
- Perception of general health, self-report of health problems (based on Census 2011 questions)[45] and effects on mobility.
- Health outcomes including assessments of mobility, self-care, usual activities, pain/discomfort, anxiety/depression and overall perception of health on a scale from 0 to 100 [using EuroQol-5 Dimensions (EQ-5D) questions].
- Satisfaction scores including perception of overall levels of satisfaction, feeling happy and anxious, on a scale from 1 to 10 (based on questions used in the Measuring National Well-being Programme), and further assessment of anxiety and depression based on the Hospital Anxiety and Depression Scale.
- Current and previous smoking status, and current alcohol consumption (using Health Survey for England questions[47]).
- Perceptions of the local area/neighbourhood, including transport, leisure activities, vandalism, litter, traffic, attractiveness and safety, as well as assessment of social participation, support, cohesion and trust.
- Type of activities carried out and frequency of carrying out vigorous, moderate, walking, sitting activities in the last 7 days (based on the short-form IPAQ).
- Cost of activities including membership fees, vouchers received and equipment bought to do physical activity.
- Attitudes to exercise.
- Television and computers/screen time assessment.
- Fruit and vegetable consumption, and usual sleeping times.

IPAQ, International Physical Activity Questionnaire.

The approaches to analysing ActiGraph data are detailed in *Chapter 3*. Simultaneous use of ActiGraph accelerometers and GPS travel recorders allowed active travel components of physical activity (i.e. walking), as well as indoor and outdoor activities, to be identified using methods previously described by the investigators[48,49] and the methods detailed in *Chapter 5*. In addition, GPS data allowed the geographical location at which different levels of physical activity occurred to be identified (from sedentary to vigorous, using established cut-off points in accelerometer data), both at baseline and at follow-up. Together, these measures allowed accelerometry data to be interpreted in depth, allowing the nature and location of recorded activities, particularly active forms of transport such as walking and cycling, to be identified. Moreover, it allowed the contribution of active transport local to place of residence to be quantified and compared between those living in East Village and control areas (see *Chapter 5*).

Environmental exposures

Geographical information systems (GIS) were used to extract objective data on features of the local environment (see *Chapter 4*). In combination with ActiGraph and GPS data from study participants, this allowed the location of different levels of physical activity (including both high and low levels of activity) to be accurately identified. This method has been used previously by the investigators to establish the important contribution of walking to school and location (including land use type) to MVPA levels in children.[49,50] A number of data sources were used to identify environmental and activity-permissive features within East Village and control areas, including Ordnance Survey (OS) MasterMap Tomography Layer (versions December 2018, May 2014, June 2015) (Ordnance Survey, URL: www.ordnancesurvey.co.uk/business-government/products/mastermap-topography; accessed September 2019), Integrated Transport Network and Transport for London (TfL)[51] sources, Olympic Delivery Authority and local authority data, as well as other online resources. In particular, OS data were used to derive indices, such as land use mix, street connectivity, residential density, walkability and connectivity indices, including walking distance to particular features of the built environment, including green space.[52]

Anthropometric measurements

Height was measured to the last complete millimetre with a portable stadiometer (Leicester Stadiometer; Seca, Birmingham, UK) at baseline and follow-up. Both weight and leg-to-leg bioimpedance were assessed using an electronic Tanita SC-240 body composition analyser (Tanita Inc., Tokyo, Japan) to provide measures of fat mass (kg) and fat-free mass (kg); body mass index (BMI) was calculated as weight/height^2 (kg/m^2). In total, eight Leicester Stadiometers and Tanita SC-240 body composition analysers were used to measure the participants. The Tanita devices were operated using factory default settings and were regularly checked in accordance with recommended review procedures.

Questionnaire data

Questionnaires were converted into electronic format using SNAP Surveys software (version 11, SNAP Surveys, London, UK), and completed by study participants using dedicated laptops. The questionnaires used established validated methodologies to collect detailed information on patterns and types of activity that were local to the place of residence. In particular, the 'Neighbourhood Physical Activity Questionnaire' provided data to examine walking within the neighbourhood,[53] and the 'Neighbourhood Environment Walking Scale' provided data on perceptions of the neighbourhood environment.[54,55] Information on self-defined ethnic origin (based on the 2011 Census[45]) and a range of social markers were recorded (including employment status, income, duration and location of work), together with home address and postcode of residence, allowing GIS-determined distance to local amenities to be measured. Questions about general health/health status,[45] well-being, anxiety and depression, including both clinical and subclinical forms of assessment suitable for use in community settings, were also used (see *Chapter 6*).[22,56–58] Physical activity was assessed using an adaptation of the short-form, self-reported International Physical Activity Questionnaire (IPAQ)[59] to provide perceived levels of physical activity in addition to objective measures. Adults were asked about their attitudes to physical activities (including both sedentary, such as screen time, and physically active forms) and factors that influence

their physical activity behaviour. Participants were asked about perceived personal, social and environmental influences on physical activity, their use of recreational space (particularly walkways and cycle paths) and facilities in their residential neighbourhood (including costs incurred). Participants were also asked about the availability, accessibility (method of travel and journey times) and usage of local amenities (walkways, cycle paths, parks, swimming pools, etc.); their perceptions of the safety of these amenities and the degree to which they permit their child independent or supervised use were also elicited. The questionnaire also included sections to ascertain levels of social participation, support, cohesion and trust.[60] These items were particularly relevant to gauge how the use and perceptions of the local area by others had an impact on individual use and how this might differ from objectively measured features of their neighbourhood. The main questionnaire is included in *Appendix 1*. Questions were repeated at follow-up, but further questions were included to capture use and frequency of use of the Olympic Park and shopping facilities in the East Village area. Additionally, given the 2-year follow-up, a further question was included to establish whether or not participants had ever lived in East Village between baseline and follow-up interviews.

Qualitative data

In addition to the rich quantitative data, focus groups among study participants in the social housing sector, who were the first to move into East Village, were carried out to identify issues of importance, particularly about perceptions and use of their local environment, and to confirm whether or not the ENABLE London study questionnaire was capturing a suitable and accurate insight of constructs that would identify environmental factors influencing health behaviour (see *Chapter 7*). GIS and GPS data were also combined with qualitative spatial narratives among study participants to explore differences in active travel associated with moving to East Village. These narratives used individual participant maps to assess how the built environment influences travel behaviour and physical activity: examining change in travel patterns, reasons for the change, purpose of travel and choice of route (see *Chapter 8*).

Sample recruited and examined

A total of 1819 households (749 social, 738 intermediate and 332 market-rent) expressed an interest in taking part in the study, of which 1006 (392 social, 421 intermediate and 193 market-rent) were examined at baseline from January 2013 to January 2016 (*Figure 1*). More than one person per household was invited to take part. In total, 1497 individuals took part: 1278 adults (520 social, 524 intermediate and 234 market-rent) and 219 children (209 social, eight intermediate and two market-rent). *Figure 2* shows the geographic home locations of study participants at baseline, which highlights the Newham focus of those in social housing, and Greater London geographic diversity of participants seeking intermediate and market-rent accommodation. The small number of children recruited was not expected given that the accommodation in East Village was largely designed for family occupation. Most of the children recruited (95%) were from the social housing sector, and very few children were recruited from intermediate and market-rent groups, which were largely adult-only households. The overall number of children was too small to provide sufficient power to detect change in physical activity; therefore, only adults were considered from here on. The smaller number of adult participants recruited from the market-rent sector reflected the limitations placed on the extent and duration of access to applicants seeking this type of accommodation in East Village. The ENABLE London cohort was predicated on recruiting 1200 adults from 1200 households and succeeded in recruiting 1278 adults from 1006 households. Given the modest imbalance between movers and non-movers, the compliance and the follow-up rate observed, the study was powered to detect a 750-step change [0.3 standard deviation (SD)] at 90% power and with a probability of 0.01 among those who move to East Village.[61]

The characteristics of the baseline sample by housing sector are summarised in *Table 1*. Participants seeking social housing in East Village were older, mainly female, and more likely to be from ethnic minority groups than the intermediate and market-rent sectors. The social housing sector was largely residing in households of four or more people (58% vs. intermediate 29% and market-rent 27%), which included children (82% vs. intermediate 18% and market-rent 10%). Only one-quarter (24%) of the

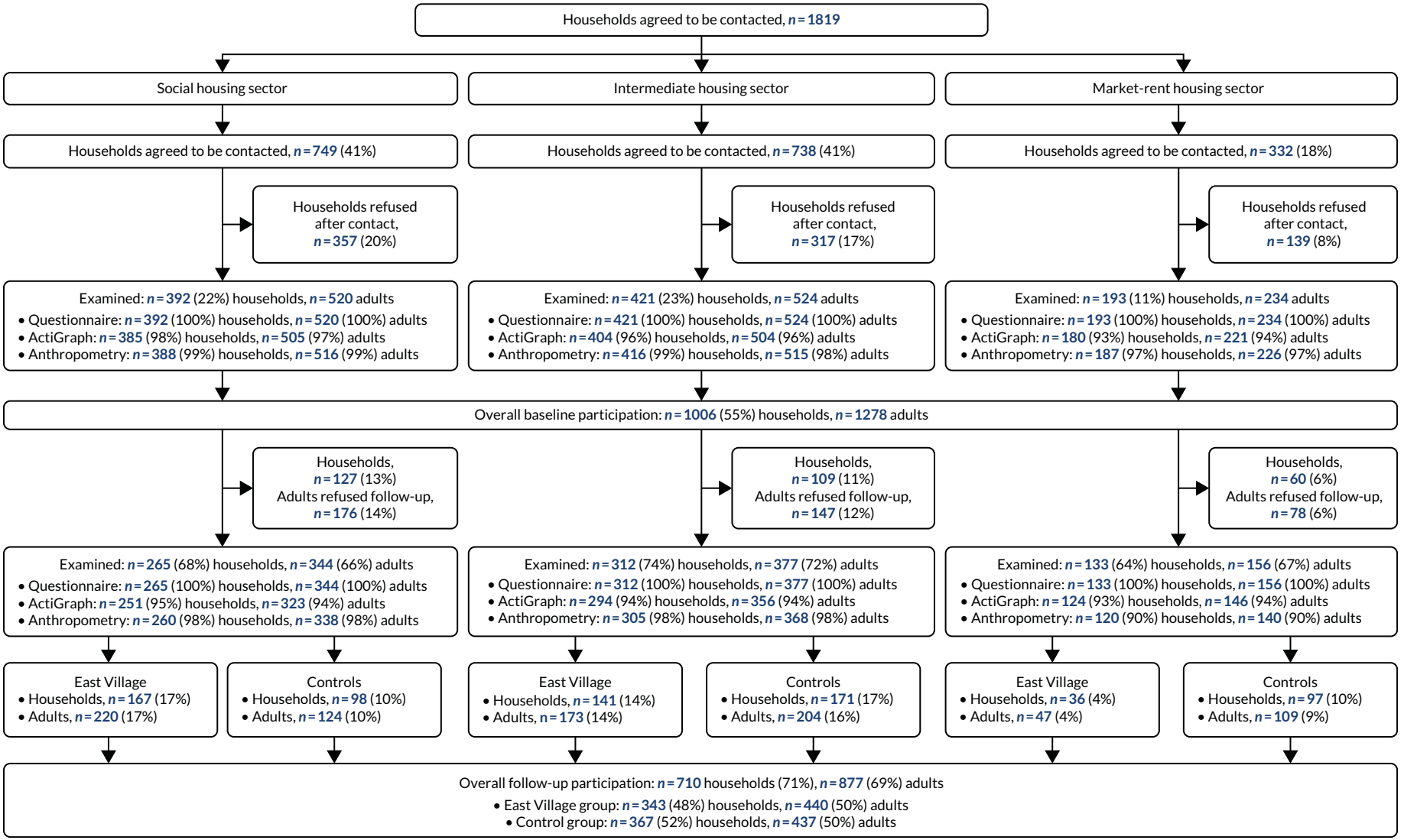

FIGURE 1 Flow diagram of households and participants examined at baseline and follow-up in the ENABLE London study. Reproduced from Ram *et al.*[61] Published by the BMJ Publishing Group Limited. This is an Open Access article distributed in accordance with the terms of the Creative Commons Attribution (CC BY 4.0) license, which permits others to distribute, remix, adapt and build upon this work, for commercial use, provided the original work is properly cited. See: http://creativecommons.org/licenses/by/4.0/.

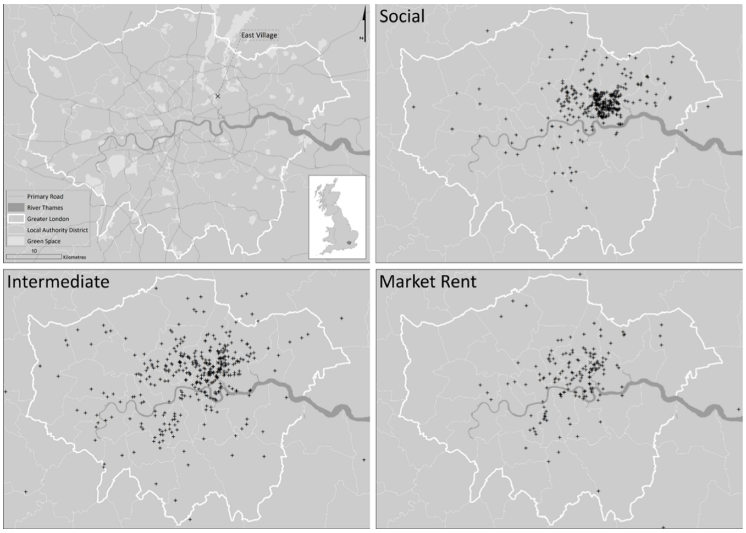

FIGURE 2 Baseline locations of social, intermediate and market-rent households participating in the ENABLE London study. Reproduced from Ram *et al.*[61] Published by the BMJ Publishing Group Limited. This is an Open Access article distributed in accordance with the terms of the Creative Commons Attribution (CC BY 4.0) license, which permits others to distribute, remix, adapt and build upon this work, for commercial use, provided the original work is properly cited. See: http://creativecommons.org/licenses/by/4.0/.

TABLE 1 Characteristics of the ENABLE London Study cohort at baseline, by housing sector

Characteristic	All housing sectors, *n* (%)	Housing sector,[a] *n* (%)		
		Social housing	Intermediate	Market-rent
Cohort				
Participants				
Households	1006 (100)	392 (52)	421 (57)	193 (58)
Adults	1278 (100)	520 (41)	524 (41)	234 (18)
Individual characteristics				
Age, median (IQR)				
Age	31 (26–40)	37 (27–44)	30 (26–35)	28 (24–33)
Sex				
Male	547 (43)	141 (27)	275 (52)	131 (56)
Female	731 (57)	379 (73)	249 (48)	103 (44)
Ethnicity				
White	617 (48)	96 (18)	358 (68)	163 (70)
Asian	214 (17)	108 (21)	77 (15)	29 (12)
Black	323 (25)	251 (48)	55 (11)	17 (7)
Mixed/other	124 (10)	65 (13)	34 (6)	25 (11)
Household-level characteristics				
Household composition				
1 person	97 (8)	28 (5)	38 (7)	31 (13)
2 people	385 (30)	88 (17)	217 (41)	80 (34)
3 people	278 (22)	101 (19)	116 (22)	61 (26)
≥ 4 people	518 (41)	303 (58)	153 (29)	62 (27)

continued

TABLE 1 Characteristics of the ENABLE London Study cohort at baseline, by housing sector (*continued*)

Characteristic	All housing sectors, *n* (%)	Housing sector,[a] *n* (%)		
		Social housing	Intermediate	Market-rent
Living with partner				
Yes	556 (44)	202 (39)	261 (50)	93 (40)
No	615 (48)	244 (47)	245 (47)	126 (54)
Unknown	107 (8)	74 (14)	18 (3)	15 (6)
Living with children				
Yes	542 (42)	425 (82)	93 (18)	24 (10)
No	736 (58)	95 (18)	431 (82)	210 (90)
Socioeconomic characteristics *Education*[b]				
Degree or equivalent/higher	736 (58)	122 (24)	428 (82)	186 (80)
Intermediate qualification	380 (30)	280 (54)	70 (13)	30 (13)
Other/none	159 (12)	117 (23)	25 (5)	17 (7)
Employment status[c]				
Employed	948 (74)	252 (49)	492 (94)	204 (87)
Unemployed	91 (7)	73 (12)	7 (1)	11 (5)
Economically inactive	236 (18)	192 (37)	25 (5)	19 (8)
NS-SEC[d]				
Higher managerial/professional	591 (46)	61 (12)	375 (72)	155 (66)
Intermediate occupations	179 (14)	62 (12)	79 (15)	38 (16)
Routine/manual	170 (13)	125 (24)	34 (6)	11 (5)
Health characteristics *General health status*				
Very good	365 (29)	140 (27)	153 (29)	72 (31)
Good	703 (55)	253 (49)	310 (59)	140 (60)
Fair	179 (14)	103 (20)	58 (11)	18 (8)
Bad	25 (2)	19 (4)	2 (0.4)	4 (2)
Very bad	6 (0.5)	5 (1)	1 (0.2)	0 (–)
Limiting longstanding illness				
Yes	162 (13)	107 (21)	41 (8)	14 (6)
Physical activity[e]				
Daily steps, mean (SD)	8950 (3190)	7803 (3303)	9684 (2924)	9337 (2990)
MVPA (minutes/day), mean (SD)	60 (26)	50 (26)	65 (23)	65 (25)
MVPA in 10-minute bouts[f]	15 (6–30)	7 (1–15)	21 (10–34)	21 (21–36)
Anthropometry				
Height (m), mean (SD)	1.69 (0.10)	1.65 (0.09)	1.71 (0.10)	1.72 (0.10)
Weight (kg)[f]	71 (62–82)	71 (63–84)	71 (62–81)	73 (61–80)
BMI (kg/m^2)[f]	25 (22–28)	26.3 (23–31)	24 (22–27)	24 (22–26)
Fat mass (kg)[f,g]	18 (13–26)	23 (16–31)	15 (11–21)	15 (11–21)

TABLE 1 Characteristics of the ENABLE London Study cohort at baseline, by housing sector (*continued*)

Characteristic	All housing sectors, *n* (%)	Housing sector,[a] *n* (%)		
		Social housing	Intermediate	Market-rent
Mental health				
Depression[h]	173 (14)	100 (21)	52 (10)	21 (9)
Anxiety[h]	392 (31)	169 (33)	146 (28)	77 (33)
Well-being				
Low levels of life satisfaction[i]	330 (26)	169 (33)	117 (22)	44 (19)
Low levels of feeling that life is worthwhile[i]	265 (21)	123 (24)	95 (18)	47 (20)
Low levels of feeling happy[i]	358 (28)	157 (30)	130 (25)	71 (30)
Neighbourhood perceptions[j]				
Crime-free, mean (SD)	2.03 (4.40)	0.69 (4.59)	2.94 (3.96)	2.95 (4.18)
Quality, mean (SD)	3.52 (4.53)	2.41 (4.58)	4.36 (4.41)	4.13 (4.20)

IQR, interquartile range; NS-SEC, National Statistics Socioeconomic Classification.
a Housing tenure being sought.
b Education: three missing responses in total (social $n = 1$; intermediate $n = 1$; market-rent $n = 1$).
c Employment status as defined by the International Labour Organization:[62] unemployed includes seeking work or on a government work scheme; economically inactive includes looking after home/family, retired, students and unable to work owing to ill health; three missing responses from social housing sector.
d National Statistics Socioeconomic Classification[63] for those employed: four economically active unclassified from 252 employed participants in the social housing sector; four economically active unclassified from 492 employed participants from the intermediate sector.
e Data available for 1230 participants.
f Non-normally distributed variables presented as median and interquartile range (lower quartile to upper quartile).
g Sixteen missing responses.
h Seven missing responses for depression; 18 missing responses for anxiety.
i Four missing responses for life satisfaction; five missing responses for worthwhile; four missing responses for happy.
j Perceptions of crime-free on scale of −10 (more perceived crime) to + 10 (less perceived crime); perceptions of quality on a scale of −12 (poor neighbourhood quality) to + 12 (better neighbourhood quality).

social housing sector had a degree qualification compared with 82% of intermediate and 80% of market-rent participants. Half of the social housing sector were employed, compared with 94% of the intermediate and 87% of the market-rent participants. There were also social gradients in the type of employment, with 12% of the social housing sector participants in higher managerial or professional occupations compared with 72% of the intermediate sector participants and 66% of the market-rent sector participants. Fewer participants in the social housing sector reported very good or good overall health (76%) than did intermediate (88%) and market-rent (91%) participants.

Follow-up participation rates

Of the 1278 adult participants from 1006 households examined at baseline, 877 (69%) adults from 710 (71%) households were examined at follow-up (see *Figure 1*). A total of 401 adult participants seen at baseline were not followed up.

Social housing sector

Social housing sector participants were followed up between February 2015 and September 2016. Of 520 adult participants from 392 households examined at baseline in the social housing sector, 66% ($n = 344$) of adult participants from 265 (68%) households were examined at follow-up. Overall, the social housing sector represented 39% ($n = 344/877$) of the adults seen at follow-up and 37% ($n = 265/710$) of households.

Intermediate housing sector

Follow-up examinations of the intermediate housing sector took place between July 2015 and September 2017. Among the 524 adults from 421 households examined at baseline, 72% ($n = 377$) from 312 (74%) households were examined at follow-up. The intermediate sector represented 43% ($n = 377/877$) of adults and 44% ($n = 312/710$) of households.

Market-rent housing sector

Market-rent participants were followed up between January 2016 and October 2017. Of 234 adults from 193 households examined at baseline, 67% ($n = 156/234$) of adults from 133 (69%) households were examined at follow-up. The market-rent sector represented 18% ($n = 156/877$) of the adults, and 19% ($n = 133/710$) of households seen at follow-up.

Follow-up rates by East Village and control groups

Half of the adult participants (50%, $n = 441/877$) had moved to East Village at follow-up and half had not; the participants who had not moved formed the control group (see *Figure 1*). Of the 441 adult participants who moved to East Village at follow-up, 50% were from the social housing sector, 39% were seeking intermediate accommodation and 11% were seeking market-rent accommodation. Within the control group ($n = 436$ adults), 28% were social housing participants, 47% were intermediate participants and 25% were market-rent participants. Among the social housing sector, participants in the East Village group had a similar sociodemographic profile to those in the control group. No differences were observed in the following characteristics: age, sex, household composition, living with partner, living with children, education, employment status, socioeconomic status [(National Statistics Socioeconomic Classification (NS-SEC)] and limiting longstanding illness (LLI) (*Table 2*). However, there were marked differences in ethnicity between East Village and control groups ($p < 0.001$), with a higher proportion of black ethnic participants in the East Village group than in the control group (55% and 32%, respectively), and a lower proportion of Asian participants in the East Village group than in the control groups (14% and 38%, respectively) in the social housing sector. For intermediate participants, the East Village and control groups were similar in household composition, living with partner, qualifications and NS-SEC, but there were differences in age between East Village and control groups ($p < 0.001$), sex ($p = 0.02$), ethnicity ($p < 0.001$), living with children ($p = 0.004$), employment status ($p = 0.02$), and LLI ($p = 0.004$). The intermediate participants in the East Village group were younger, less likely to be female and living with children, and reported a LLI, and were more likely to be of white ethnicity, employed and in intermediate occupations than the control group (see *Table 2*). Market-rent participants in the East Village and control groups were similar in their baseline sociodemographic profile, with little difference observed. Differences in baseline physical activity levels, anthropometry, neighbourhood perceptions, mental health and well-being outcomes, and the analytic approach used for respective outcomes, are outlined in *Chapters 3–6*.

Conclusions

The ENABLE London cohort provides a unique opportunity to examine the impact of a major and focused change in the urban built environment, associated with the rapid repurposed East Village development after the London 2012 Olympic and Paralympic Games, on the physical activity patterns and other health-related behaviours of the local population, particularly those from less privileged backgrounds. It provides an important test of principle that the built environment can alter health behaviours and health outcomes. If this is shown to be the case, the results will inform evidence-based urban planning in the future, and the way in which environmental changes have an impact on health inequalities.

TABLE 2 Baseline characteristics of the follow-up cohort ($n = 877$) by East Village and control group, and housing sector

Characteristic	All housing sectors ($N = 877$)			Housing sector								
				Social ($N = 344$)			Intermediate ($N = 377$)			Market rent ($N = 156$)		
	East Village ($N = 441$), *n* (%)	Control ($N = 436$), *n* (%)	*p*-value	East Village ($N = 220$), *n* (%)	Control ($N = 124$), *n* (%)	*p*-value	East Village ($N = 174$), *n* (%)	Control ($N = 203$), *n* (%)	*p*-value	East Village ($N = 47$), *n* (%)	Control ($N = 109$), *n* (%)	*p*-value
Individual characteristics												
Age group (years)												
16–24	104 (24)	75 (17)		47 (21)	18 (15)		38 (22)	30 (15)		19 (40)	27 (25)	
25–34	194 (44)	185 (42)		61 (28)	32 (26)		113 (65)	100 (49)		20 (43)	53 (49)	
35–49	123 (28)	138 (32)		95 (43)	66 (53)		22 (13)	61 (30)		6 (13)	11 (10)	
≥ 50	20 (5)	38 (9)	0.01[a]	17 (8)	8 (6)	0.27[a]	1 (1)	12 (6)	< 0.001[a]	2 (4)	18 (17)	0.07[a]
Sex												
Female	247 (56)	248 (57)	0.80[a]	158 (72)	91 (73)	0.76[a]	70 (40)	107 (53)	0.02[a]	19 (40)	50 (40)	0.53[a]
Ethnicity												
White	212 (48)	225 (51)		38 (17)	25 (20)		139 (80)	122 (60)		35 (74)	78 (72)	
Asian	56 (13)	91 (21)		31 (14)	47 (38)		18 (10)	35 (17)		7 (15)	9 (8)	
Black	131 (30)	81 (19)		120 (55)	40 (32)		9 (5)	32 (16)		2 (4)	9 (8)	
Mixed/other	42 (10)	39 (9)	< 0.001[a]	31 (14)	12 (10)	< 0.001[a]	8 (5)	14 (7)	< 0.001[a]	3 (6)	13 (12)	0.42[b]
Household characteristics												
Household composition												
1 person	30 (7)	54 (12)		14 (6)	25 (4)		9 (5)	17 (8)		7 (15)	12 (11)	
2 people	127 (29)	174 (40)		33 (15)	47 (16)		76 (44)	82 (40)		18 (38)	45 (41)	
3 people	94 (21)	121 (28)		45 (20)	40 (13)		38 (22)	52 (26)		11 (23)	29 (27)	
≥ 4 people	190 (43)	87 (20)	0.20[a]	128 (58)	12 (67)	0.22[a]	51 (29)	52 (26)	0.45[a]	11 (23)	23 (21)	0.88[a]

continued

TABLE 2 Baseline characteristics of the follow-up cohort ($n = 877$) by East Village and control group, and housing sector (*continued*)

Characteristic	All housing sectors ($N = 877$)			Housing sector								
				Social ($N = 344$)			Intermediate ($N = 377$)			Market rent ($N = 156$)		
	East Village ($N = 441$), *n* (%)	Control ($N = 436$), *n* (%)	*p*-value	East Village ($N = 220$), *n* (%)	Control ($N = 124$), *n* (%)	*p*-value	East Village ($N = 174$), *n* (%)	Control ($N = 203$), *n* (%)	*p*-value	East Village ($N = 47$), *n* (%)	Control ($N = 109$), *n* (%)	*p*-value
Living with partner												
Yes	186 (42)	210 (48)		84 (38)	60 (55)		82 (47)	101 (50)		20 (43)	49 (45)	
No	215 (49)	205 (47)		103 (47)	50 (46)		88 (51)	96 (47)		24 (51)	59 (54)	
Unknown	40 (9)	21 (5)	0.02[a]	33 (15)	14 (13)	0.17[a]	4 (2)	6 (3)	0.79[b]	3 (6)	1 (1)	0.17[b]
Living with children												
Yes	206 (47)	172 (39)	0.03[a]	177 (20)	109 (12)	0.08[a]	24 (14)	52 (26)	0.004[a]	5 (11)	11 (10)	0.92[a]
Socioeconomic characteristics												
Education[c]												
Degree or equivalent/higher	249 (57)	287 (66)		55 (25)	34 (27)		154 (89)	166 (82)		40 (85)	87 (80)	
Intermediate qualification	137 (31)	102 (23)		118 (54)	59 (48)		15 (9)	26 (13)		4 (9)	17 (16)	
Other/none	55 (13)	45 (10)	0.01[a]	47 (21)	30 (24)	0.60[a]	5 (3)	11 (5)	0.18[a]	3 (6)	4 (4)	0.39[b]
Employment status[d]												
Employed	307 (70)	347 (80)		98 (45)	67 (54)		169 (97)	183 (90)		40 (85)	97 (89)	
Unemployed	36 (8)	22 (5)		33 (15)	12 (10)		1 (1)	4 (2)		2 (4)	6 (6)	
Economically inactive	97 (22)	67 (15)	0.004[a]	88 (40)	45 (36)	0.18[a]	4 (2)	16 (8)	0.02[b]	5 (11)	6 (6)	0.51[b]
NS-SEC[e]												
Higher managerial/ professional	179 (41)	246 (56)		23 (24)	24 (36)		124 (74)	146 (81)		32 (80)	76 (78)	
Intermediate occupations	69 (16)	54 (12)		27 (28)	16 (24)		34 (20)	22 (12)		8 (20)	16 (16)	
Routine/manual	56 (13)	44 (10)	0.003[a]	46 (48)	26 (39)	0.23[a]	10 (10)	13 (7)	0.12[a]	0 (0)	5 (5)	0.43[b]

Characteristic	All housing sectors (*N* = 877)			Housing sector								
				Social (*N* = 344)			Intermediate (*N* = 377)			Market rent (*N* = 156)		
	East Village (*N* = 441), *n* (%)	Control (*N* = 436), *n* (%)	*p*-value	East Village (*N* = 220), *n* (%)	Control (*N* = 124), *n* (%)	*p*-value	East Village (*N* = 174), *n* (%)	Control (*N* = 203), *n* (%)	*p*-value	East Village (*N* = 47), *n* (%)	Control (*N* = 109), *n* (%)	*p*-value
Health characteristics												
General health status												
Very good	134 (30)	112 (26)		65 (30)	27 (22)		52 (30)	52 (26)		17 (36)	33 (30)	
Good	234 (53)	253 (58)		101 (46)	61 (49)		107 (61)	125 (62)		26 (55)	67 (61)	
Fair	63 (14)	59 (14)		45 (20)	28 (23)		15 (9)	24 (12)		3 (6)	7 (6)	
Bad	8 (2)	12 (3)		7 (3)	8 (6)		0 (–)	2 (1)		1 (2)	2 (2)	
Very bad	2 (1)	0 (–)	0.23[a]	2 (1)	0 (–)	0.27[a]	0 (–)	0 (–)	0.35	0 (–)	0 (–)	0.90
LLI												
Yes	58 (13)	59 (14)	0.87[a]	49 (22)	28 (23)	0.95[a]	6 (3)	23 (11)	0.004[a]	3 (6)	8 (7)	1.00[b]

a Chi-squared.
b Fisher's exact test.
c Education: two missing responses.
d Employment status as defined by International Labour Organization:[62] unemployed includes seeking work or on a government work scheme; economically inactive includes looking after home/family, retired, students and unable to work owing to ill health; one missing response in social housing sector.
e NS-SEC for those employed: three economically active unclassified from 165 employed participants in the social housing sector; three economically active unclassified from 352 employed participants in the intermediate sector.

Chapter 3 Physical activity and adiposity: baseline and 2-year follow-up findings from the ENABLE London study

Introduction

The ENABLE London is a longitudinal study evaluating how active urban design influences the health and well-being of people moving into the former London 2012 Olympic and Paralympic Games Athletes' Village, now known as 'East Village'.[61] East Village is a purpose-built, mixed-use, high-rise residential development, specifically designed to encourage healthy active living by improving walkability and access to public transport, which consists of a mix of social housing, intermediate (including affordable rent, shared ownership and shared equity) housing, and market-rent housing.[61] This chapter draws on baseline data (prior to any potential move to East Village) to:

1. examine predictors of physical activity and adiposity (measured objectively using accelerometry and bioelectrical impedance), including the housing tenure being sought and participants' perceptions of their neighbourhood
2. examine whether or not physical activity patterns over 7 days vary by housing sector
3. examine whether or not adjustment for perceptions of the neighbourhood environment reduce housing sector differences in physical activity and adiposity.

Given the longitudinal design, the study also provides a unique opportunity to:

4. examine change in objectively measured physical activity and adiposity after 2 years among those who moved to East Village compared with those who did not, which will add robust evidence to the debate about the effect of the built environment on health.

The study was also able to:

5. objectively quantify the quality of the built environment in which people lived among those followed up at both time points using GIS-derived methods
6. gauge the change in neighbourhood perceptions associated with moving to East Village.

Methods

Participants

Examining Neighbourhood Activities in Built Living Environments in London (ENABLE London) study participants were recruited from those seeking or who had applied for new accommodation in East Village. There were three types of housing tenure being sought based on level of income: social (provided by the local authority or housing association at subsidised rates), intermediate (a mixture of shared ownership, shared equity and affordable rent) and market-rent. The inclusion criteria was broad and included anyone interested/applying for single or multiple occupancy accommodation in East Village. There was no explicit exclusion criteria; adults of any age, gender, ethnic group, with or without handicap, were invited to participate. Current housing status was strongly linked to aspirational housing status; those seeking social accommodation were currently in social housing or on social housing waiting lists, and those seeking intermediate and market-rent accommodation were largely in privately rented housing. Aspirational housing tenure is integral to the design of ENABLE London, and we have

shown that this provides a clear socioeconomic marker of study participants. For example, those seeking social housing in East Village are more likely to be unemployed, less educated and more likely to represent ethnic minorities (a classic marker of socioeconomic vulnerability), compared with those seeking affordable and market-rent accommodation (see *Chapter 2*).[61] We have also shown key differences in mental health and well-being between housing sectors; those seeking social housing were more likely to be depressed, anxious and have poorer well-being than other housing sectors (see *Chapter 6*).[64] Moreover, this is entirely consistent with earlier studies that found both current housing tenure and aspirational housing tenure are associated with a variety of health outcomes, including mental health and measures of general health.[21,65]

Assessments of participants were carried out in their place of residence before any potential move to East Village, and 2 years later (February 2015 to October 2017) for those who had moved to East Village, moved elsewhere or not moved.[66]

Measures

Physical activity

Participants wore a hip-mounted ActiGraph GT3X+ accelerometer during waking hours over a period of 7 days. Accelerometers provided daily measures of steps (primary outcome), time spent in moderate or vigorous physical activity and time spent sedentary, using established thresholds [sedentary < 100 counts per minute (CPM), moderate physical activity ≥ 1952 CPM].[67] Periods of non-wear time were defined as ≥ 60 minutes of zero values, allowing for a 2-minute spike tolerance, to provide daily wear time. We excluded days of accelerometer data where the registered wear time was < 540 minutes. Participants with at least 1 day of data were included in the baseline analysis; those with at least 1 day of data at both baseline and follow-up were retained in the longitudinal analysis. We have previously used at least 1 day of 540 minutes (9 hours) of registered time to represent a satisfactory recording of daily activity in a randomised controlled trial of older but overlapping age groups.[68] The at least 1 day of 540 minutes cut-off point was chosen to lessen attrition bias, and was used in this study to maximise inclusion of hard to reach groups, that is those from social housing, who notoriously comply less and recorded less physical activity data.

Adiposity

The protocol for body size and adiposity measurement was identical at baseline and at follow-up. Height was measured to the last complete millimetre using a portable stadiometer. A Tanita SC-240 Body Composition Analyser was used to measure weight to the nearest kilogram and leg-to-leg bioelectrical impedance, from which fat-free mass and fat mass were estimated. BMI was calculated as weight (kg)/height $(m)^2$ and percentage fat mass was calculated as $100 \times$ fat mass (kg)/weight (kg).

Covariates

A team of trained fieldworkers administered self-completion questionnaires using a laptop during home visits (see *Table 1*). Age, sex, self-defined ethnicity, work status and occupation, and whether or not the participant had a LLI or disability (lasting or expected to last at least 12 months) were collected via a questionnaire. Participants were defined as 'white', 'Asian', 'black', 'mixed' or 'other'; the last two categories were combined in the analysis. Occupation-based socioeconomic status was coded using the NS-SEC to categorise participants into 'higher managerial or professional occupations', 'intermediate occupations' and 'routine or manual occupations'.[63] An additional 'economically inactive' category included those seeking employment, those unable to work owing to disability or illness, those who were retired, those looking after home and family, and students. We sought information on educational attainment; participants were categorised into 'degree or equivalent/higher', 'intermediate qualifications' (including A levels and General Certificates of Secondary Education), and 'other/none' (including work-based or foreign qualifications).

Built environment variables

Residential built environment characteristics were derived using GIS data at baseline and at follow-up for those households in the Greater London area. These included network distance from home to the closest park (using data from the London Development Database),[69] public transport access,[51] and measures of neighbourhood walkability, land use mix, residential density and street connectivity computed within a 1-km street network home-centred buffer (see *Chapter 4*).

Neighbourhood perceptions

Participants completed questionnaires assessing neighbourhood perceptions; the methods used are outlined further in *Chapter 6*.[64] In brief, five items assessed perceived crime (e.g. 'There is a lot of crime in my neighbourhood'; Cronbach's $\alpha = 0.87$) and six items assessed neighbourhood quality (e.g. 'This area is a place I enjoy living in'; Cronbach's $\alpha = 0.78$). Responses on items were summed and scores ranged from −10 to +10 for perceived crime and −12 to +12 for perceived quality, such that positive scores indicate less perceived crime and better neighbourhood quality whereas negative scores indicate more perceived crime and poorer quality. The scales were derived following an exploratory factor analysis of 14 questions regarding the neighbourhood (see *Report Supplementary Material 1*). Two neighbourhood perception scores, measuring crime-free neighbourhood (i.e. vandalism, feeling unsafe to walk in neighbourhood, presence of threatening groups) and neighbourhood quality (i.e. accessible features, attractiveness and enjoyment of living in neighbourhood), were derived at baseline using exploratory factor analysis on 14 neighbourhood perception items in the questionnaire,[64] and the same items were used to obtain scores at follow-up.

Statistical analysis

All analyses were carried out using Stata® Special Edition version 15 for Windows® (StataCorp LP, College Station, TX, USA).

To obtain average physical activity variables, we fitted a multilevel linear model for each outcome to allow for repeated measurements of daily physical activity, by fitting participant as a random effect and adjusting for day of the week, day order of recording and month as fixed effects. Raw level one residuals were obtained from the model and a within-person average value of each outcome variable was obtained by averaging these raw residuals. The average of these raw residuals for each participant was added to the sample mean for that particular physical variable to derive an unbiased average level of each physical activity variable at baseline and at follow-up for each person.

Baseline analyses

Physical activity and adiposity outcome variables were inspected for normality; BMI was log-transformed because of its skewed distribution. Multilevel linear regression models were fitted, mutually adjusted for housing sector and participant characteristics (sex, age group, ethnic group and LLI) as fixed effects, with a random effect to allow for household clustering. Age groups (16–24 years, 25–34 years, 35–49 years and $\geq$ 50 years) were chosen to give a wide spread of ages representative of young adults, young professionals, early middle age and later middle-age/older-age people. Residuals did not show departure from linearity, suggesting that the model assumptions were appropriate. Absolute differences or percentage differences for log-transformed outcomes (i.e. BMI) are presented by sex, age group, ethnic group, LLI and housing sector. Sensitivity analyses examined whether or not associations remained when the sample was restricted to 931 participants (84%) with $>$ 4 days of $\geq$ 540 minutes per day of recording.

To assess differences in physical activity by day of the week as opposed to overall levels of physical activity, we took the following approach. Daily physical activity data were examined using multilevel models with random effects to allow for multiple days of recording within-person and household clustering. An interaction between housing sector and day of the week was fitted and models were adjusted for sex, age group, ethnic group, LLI, day order of recording and month of measurement as fixed effects.

The associations between neighbourhood perception scales and adiposity and physical activity outcomes at baseline were examined. Each of the neighbourhood quality and crime scores were included in the models as quintiles, to examine the differences in outcomes between the top and bottom quintile. The effect of adjustment for neighbourhood perception on differences in the adiposity and physical activity levels between housing sectors was examined. If associations between outcomes and neighbourhood perceptions appeared linear, models examining housing sector differences were additionally adjusted for neighbourhood perceptions as a continuous variable.

Follow-up analyses

Multilevel linear regression models were fitted to examine the effect of moving to East Village on levels of physical activity and adiposity compared with controls who did not live in East Village (in all cases the distributions of residuals from the models were checked for normality). The primary outcome was specified a priori to be daily steps; secondary outcomes included time spent in MVPA (both total and in $\geq$ 10 minutes bouts per week), the daily sedentary time, BMI and fat mass percentage.[61] Average daily steps at follow-up was regressed on average daily steps at baseline, adjusting for East Village or control group as a fixed effect and baseline household as a random effect to allow for household clustering. Throughout, an alpha of less than 0.05 (p-value < 0.05) was used to determine the statistical significance of effects. Because of baseline differences in sociodemographic factors, further adjustment for participant characteristics, including sex, age group and ethnic group, were examined. Stratified models by housing tenure examined the effect in the different housing sectors (work status, occupation and child status were not adjusted for as these were strongly related to housing status). We also included an interaction term between East Village/control group and housing sector. Sensitivity analyses were carried out for daily steps, the primary outcome, by:

1. restricting the sample to those with at least 4 days of $\geq$ 540 minutes' recording at baseline and at follow-up
2. repeating analyses for weekdays only and weekend days only (as this will modify exposure to the residential built environment)
3. comparing East Village participants with controls who remained at their baseline address at follow-up and controls who had moved elsewhere
4. examining the impact of missing accelerometry data at follow-up using imputation methods.

Results

At baseline

Overall participation rates and participation rates by housing sectors were outlined earlier (see *Chapter 2*). For the main outcomes of interest, complete data on adiposity were available for 1240 participants (97%); of these, a subset of 1107 participants (89%) met the inclusion criteria for analyses of objectively measured physical activity. Participant characteristics (age, sex, ethnicity) and levels of adiposity were similar among those who did and did not provide physical activity data; however, participants from black and Asian ethnic groups were less likely to provide physical activity data. *Report Supplementary Material 2* shows characteristics of participants at baseline for the 1240 adults with measurements of adiposity at baseline, which are similar to those with physical activity data.

Adjusted mean levels of physical activity, and adiposity outcomes by housing sector and participant characteristics, are shown in *Report Supplementary Material 3*. *Table 3* shows the association of housing sector and other participant characteristics with objectively measured physical activity (steps, time spent in MVPA, time spent in MVPA in $\geq$ 10-minute bouts) and BMI and percentage fat mass. Participants seeking social housing had markedly lower levels of steps, MVPA and MVPA in $\geq$ 10-minute bouts and markedly higher BMI and percentage fat mass than those seeking intermediate housing, although there were no differences between those seeking market-rent and those seeking intermediate accommodation.

TABLE 3 Associations between baseline physical activity and adiposity outcomes by participant characteristics

		Daily steps[a]			Daily minutes spent in MVPA[a]			Daily minutes spent in MVPA in ≥ 10-minute bouts[a]			BMI (kg/m²)[b]			Fat mass (%)		
	n	Difference[c]	95% CI	*p*-value	Difference[c]	95% CI	*p*-value	Difference[c]	95% CI	*p*-value	Difference[c]	95% CI	*p*-value	Difference[c]	95% CI	*p*-value
Sex																
Male (reference)	522			–			–			–			–			–
Female	718	−570	−946 to −194	0.003	−9.3	−12.2 to −6.4	< 0.0001	−4.1	−6.1 to −2.0	< 0.001	−1.2	−3.2 to 0.9	0.26	11.1	10.3 to 12.0	< 0.0001
Age group (years)																
16–24 (reference)	269			–			–			–			–			–
25–34	531	502	11 to 992	0.04	4.0	0.2 to 7.9	0.04	1.0	−1.9 to 3.8	0.51	6.3	3.5 to 9.1	< 0.0001	3.2	2.1 to 4.3	< 0.0001
35–49	358	699	173 to 1224	0.01	3.9	−0.2 to 8.0	0.07	−1.1	−4.0 to 1.8	0.46	13.4	10.2 to 16.6	< 0.0001	6.4	5.2 to 7.6	< 0.0001
≥ 50	82	−9	−832 to 813	0.98	−6.0	−12.4 to 0.5	0.07	−2.0	−6.8 to 2.7	0.40	17.6	12.6 to 22.9	< 0.0001	9.2	7.3 to 11.0	< 0.0001
Ethnic group																
White (reference)	595			–			–			–			–			–
Black	314	−1116	−1657 to −575	< 0.0001	−7.4	−11.7 to −3.2	< 0.001	−6.6	−9.8 to −3.4	< 0.0001	6.2	3.3 to 9.3	< 0.0001	3.6	2.4 to 4.8	< 0.0001
Asian	210	−1409	−1972 to −845	< 0.0001	−11.5	−15.9 to −7.0	< 0.0001	−8.1	−11.4 to −4.8	< 0.0001	−0.3	−3.1 to 2.7	0.85	0.02	−1.2 to 1.3	0.97
Other/mixed	121	−430	−1100 to 239	0.21	−4.6	−9.8 to 0.7	0.09	−4.0	−7.9 to −0.04	0.05	1.3	−2.3 to 5.0	0.48	1.0	−0.5 to 2.5	0.18
LLI																
No (reference)	1087			–			–			–			–			–
Yes	153	−1081	−1666 to −496	< 0.001	−5.7	−10.3 to −1.1	0.01	−2.8	−6.1 to 0.5	0.10	4.3	1.1 to 7.5	0.01	1.6	0.3 to 2.9	0.01
Housing sector																
Social	512	−1125	−1629 to −620	< 0.0001	−7.5	−11.5 to −3.6	< 0.001	−6.5	−9.5 to −3.5	< 0.0001	5.0	2.2 to 7.8	< 0.001	2.7	1.5 to 3.8	< 0.0001
Intermediate (reference)	503			–			–			–			–			–
Market-rent	225	−104	−633 to 424	0.70	2.3	−1.9 to 6.4	0.29	2.8	−0.3 to 6.0	0.08	−0.8	−3.6 to 2.0	0.57	−0.2	−1.4 to 1.0	0.70

a Missing data for 133 participants.
b Percentage differences are presented for BMI, which was log-transformed for analysis.
c Difference in adiposity/physical activity.

Notes
All differences and percentage differences are mutually adjusted for sex, age group, ethnic group, LLI, housing sector and a random effect to allow for clustering at household level. MVPA and MVPA in ≥ 10-minute bouts are an average daily estimate, obtained from averaging a participant's weekly total.

All physical activity measures were lower among females. Steps and MVPA were slightly higher in 25- to 34-year-olds and steps were also higher among 35- to 49-year-olds than among 16- to 24-year-olds; however, there were no age group differences for MVPA in ≥ 10-minute bouts. Participants of black and Asian ethnicities had lower levels of steps, MVPA and MVPA in ≥ 10-minute bouts than people of white ethnicity. Participants who reported having a LLI had lower levels of steps and MVPA, but not MVPA in ≥ 10-minute bouts. Percentage fat mass was higher in females than males, although there was no difference in BMI (see *Table 3*). BMI and percentage fat mass were higher among all older age groups than among 16- to 24-year-olds. Participants of black ethnicity had higher levels of BMI and percentage fat mass than people of white ethnicity; there were no differences in BMI and percentage fat mass between Asian or other/mixed ethnic groups and people of white ethnicity. Those with a LLI had higher levels of both BMI and percentage fat mass. Educational attainment level was not associated with any of the outcomes once housing sector had been adjusted for, and adjustment for educational attainment did not materially alter housing sector differences in physical activity or other outcomes (data not presented).

Sensitivity analyses for physical activity outcomes were carried out in 931 participants who wore an ActiGraph for ≥ 4 days with ≥ 540 minutes of recording per day at baseline (see *Report Supplementary Material 4*). There were no differences between market-rent and intermediate groups (consistent with the main analysis presented in *Table 3*). Differences between social and intermediate groups were broadly similar with the results presented in *Table 3* for the main analysis.

Baseline differences in physical activity variables between housing sectors were examined by day of the week to explore whether or not differences between sectors were consistent across the week (*Figure 3*). Levels of physical activity [steps (*Figure 3a*), MVPA (*Figure 3b*) and MVPA in ≥ 10-minute bouts (*Figure 3c*)] were generally consistent across weekdays (Monday to Friday) among all groups. In the intermediate group, steps were higher on Saturdays and lower on Sundays; MVPA and MVPA in ≥ 10-minute bouts were lower on Sundays, but there was no difference on Saturdays compared with weekday activity. In the market-rent sector, steps, MVPA and MVPA in ≥ 10-minute bouts were higher on Saturdays and similar to

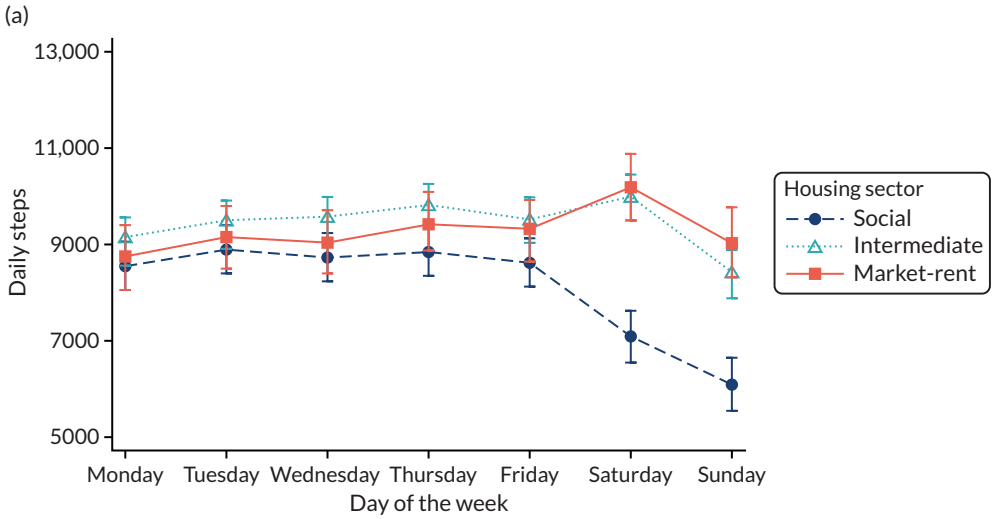

FIGURE 3 Daily physical activity by day of the week and housing sector: $N = 6206$ days from 1107 participants. Means and 95% CIs are adjusted for sex, age group, ethnic group, LLI, month of recording, day order of recording, day of week, housing sector, an interaction between housing sector and day of week and random effects to allow for multiple days of measurement and clustering of participants within households. Reproduced from Nightingale *et al.*[70] © Author(s) (or their employer(s)) 2018. Re-use permitted under CC BY. Published by BMJ. This is an open access article distributed in accordance with the Creative Commons Attribution 4.0 Unported (CC BY 4.0) license, which permits others to copy, redistribute, remix, transform and build upon this work for any purpose, provided the original work is properly cited, a link to the licence is given, and indication of whether changes were made. See: https://creativecommons.org/licenses/by/4.0/. (*continued*)

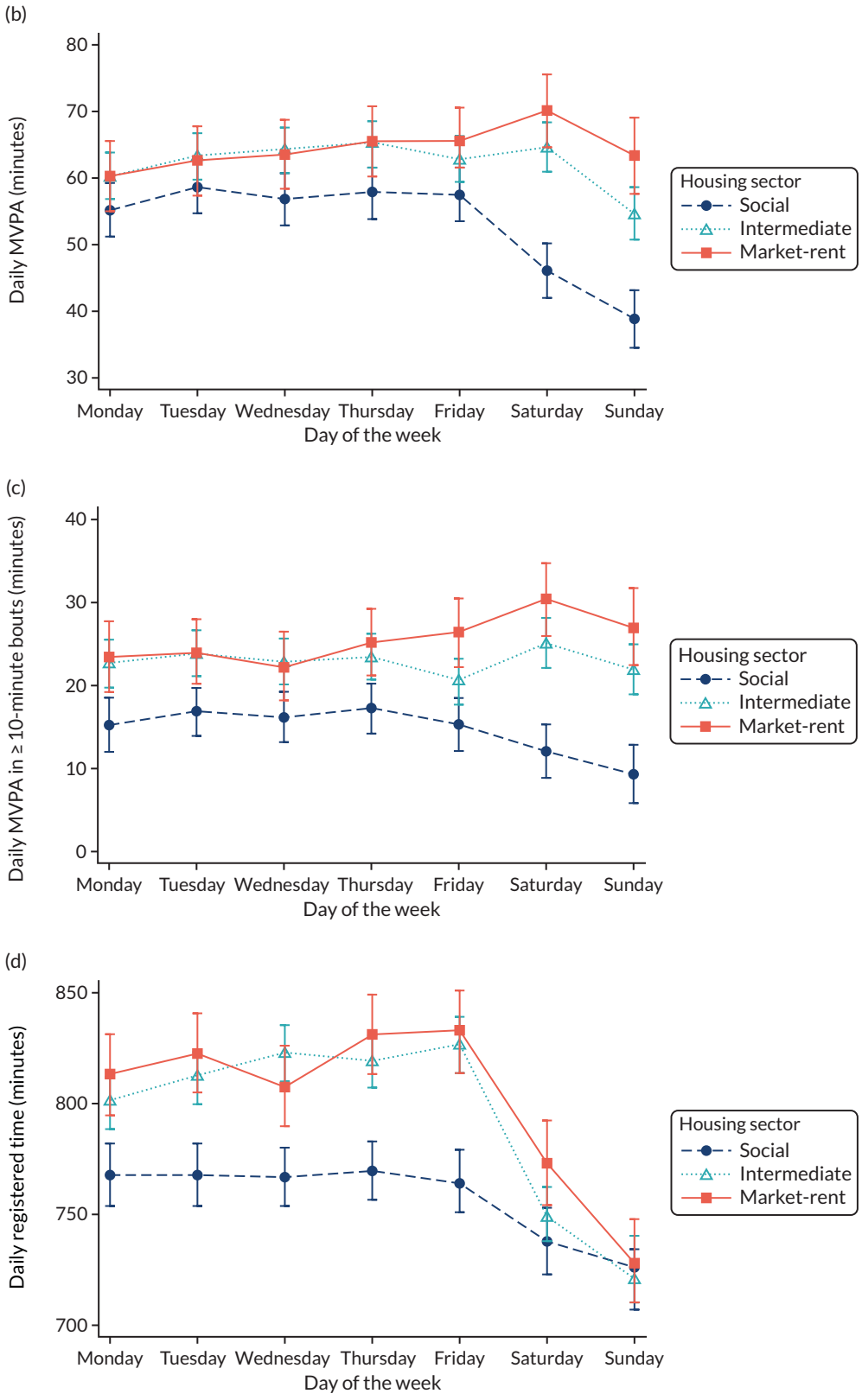

FIGURE 3 Daily physical activity by day of the week and housing sector: $N = 6206$ days from 1107 participants. Means and 95% CIs are adjusted for sex, age group, ethnic group, LLI, month of recording, day order of recording, day of week, housing sector, an interaction between housing sector and day of week and random effects to allow for multiple days of measurement and clustering of participants within households. Reproduced from Nightingale *et al.*[70] © Author(s) (or their employer(s)) 2018. Re-use permitted under CC BY. Published by BMJ. This is an open access article distributed in accordance with the Creative Commons Attribution 4.0 Unported (CC BY 4.0) license, which permits others to copy, redistribute, remix, transform and build upon this work for any purpose, provided the original work is properly cited, a link to the licence is given, and indication of whether changes were made. See: https://creativecommons.org/licenses/by/4.0/.

weekdays on Sundays. In the social group, steps, MVPA and MVPA in ≥ 10-minute bouts were on average lower on Saturdays and lower still on Sundays. Registered time of recorded physical activity (*Figure 3d*) was lowest on average in the social group during weekdays, decreasing on Saturdays and Sundays. The intermediate and market-rent groups had higher levels of registered time during weekdays than the social group, which decreased on average on Saturdays and Sundays (despite recording more steps and minutes in MVPA, suggesting a higher intensity of activity). Mean levels of steps, MVPA, and MVPA in ≥ 10-minute bouts on weekdays, and differences on Saturday and Sunday compared with weekdays, are shown by housing sector in *Report Supplementary Material 5*. The marked differences in activity between weekdays and weekend days in the social group were not explained by differences in registered time.

Associations between perceived neighbourhood quality and crime scales, and physical activity and adiposity outcomes are shown in *Table 4*, adjusted for the participant characteristics (see *Table 3*). Participants with the most positive perceptions of neighbourhood quality (highest quintile) had higher steps, recorded longer durations of MVPA and had a lower BMI than those who had the most negative perceptions of neighbourhood quality (lowest quintile). There were no significant associations between perceptions of neighbourhood crime and physical activity or adiposity.

The effect of adjustment for perceived neighbourhood quality on the differences in physical activity and adiposity between housing sector groups is presented in *Table 5*. All associations between perceived neighbourhood quality and crime-free neighbourhood and outcome variables were approximately linear and were therefore fitted as continuous variables in the model. In addition, associations between perceived neighbourhood quality and crime-free neighbourhood and outcome variables were similar across the three housing sectors (all $p > 0.05$). Adjustment for perceptions of neighbourhood quality reduced the differences in steps (by 10%), MVPA (by 10%) and MVPA in ≥ 10-minute bouts (by 7%), BMI (by 10%) and percentage fat mass (by 6%) between the social and intermediate groups. Differences between market-rent and intermediate groups in adiposity and physical activity variables were not

TABLE 4 Associations between baseline physical activity and adiposity outcomes and neighbourhood perceptions scales

	Perceptions of neighbourhood					
	Quality			Crime-free		
Outcome	Difference[a]	95% CI	*p*-value	Difference[a]	95% CI	*p*-value
***Physical activity* (N = *1107*)**						
Daily steps	677	108 to 1247	0.02	−63	−713 to 587	0.85
Daily MVPA (minutes)	4.5	0.02 to 9.0	0.05	1.1	−4.0 to 6.2	0.68
Daily MVPA in ≥ 10-minute bouts (minutes)	2.7	−0.6 to 6.0	0.11	2.4	−1.4 to 6.1	0.22
***Adiposity* (N = *1240*)**						
Body mass index (kg/m^2)[b]	−3.6	−6.5 to −0.6	0.02	−2.1	−5.4 to 1.3	0.21
Fat mass (%)	−1.2	−2.5 to 0.06	0.06	−0.8	−2.2 to 0.7	0.30

a Difference or percentage difference in outcome between the highest and lowest quintiles for each neighbourhood scale.
b Percentage differences are presented for BMI, which was log-transformed for analysis.
Notes
All differences and percentage differences are adjusted for sex, age group, ethnic group, LLI, housing sector and a random effect to allow for clustering at household level. MVPA and MVPA in ≥ 10-minute bouts are an average daily estimate, obtained from averaging a participant's weekly total.

TABLE 5 Baseline physical activity and adiposity differences between housing sectors: adjustment for perceptions of neighbourhood quality

Outcome	Housing sector	Model 1[a]			Model 2[b]		
		Difference[c]	95% CI	*p*-value	Difference[c]	95% CI	*p*-value
***Physical activity* (N = *1107*)**							
Daily steps	Social	−1125	−1629 to −620	< 0.0001	−1016	−1531 to −501	< 0.001
	Intermediate	Reference group					
	Market-rent	−104	−633 to 424	0.70	−96	−624 to 431	0.72
Daily MVPA (minutes)	Social	−7.5	−11.5 to −3.6	< 0.001	−6.8	−10.8 to −2.7	0.001
	Intermediate	Reference group					
	Market-rent	2.3	−1.9 to 6.4	0.29	2.3	−1.8 to 6.5	0.27
Daily MVPA in ≥ 10-minute bouts (minutes)	Social	−6.5	−9.5 to −3.5	< 0.0001	−6.0	−9.1 to −3.0	< 0.001
	Intermediate	Reference group					
	Market-rent	2.8	−0.3 to 6.0	0.08	2.8	−0.3 to 6.0	0.08
***Adiposity* (N = *1240*)**							
Body mass index (kg/m^2)[d]	Social	5.0	2.2 to 7.8	< 0.001	4.5	1.7 to 7.3	0.002
	Intermediate	Reference group					
	Market-rent	−0.8	−3.6 to 2.0	0.57	−0.9	−3.6 to 2.0	0.55
Fat mass (%)	Social	2.7	1.5 to 3.8	< 0.0001	2.5	1.4 to 3.6	
	< 0.0001		Intermediate	Reference group			
	Market-rent	−0.2	−1.4 to 1.0	0.70	−0.2	−1.4 to 0.9	0.68

a Model 1: adjusted for sex, age group, ethnic group, LLI and clustering at household level (random effect).
b Model 2: adjusted as model 1 plus neighbourhood quality scale (added as a continuous variable).
c Difference or percentage difference compared with the intermediate group.
d Percentage differences are presented for BMI, which was log-transformed for analysis.

Note
MVPA and MVPA in ≥ 10-minute bouts are an average daily estimate, obtained from averaging a participant's weekly total.

statistically significant before or after adjustment. Larger proportions of the social–intermediate group differences in steps, MVPA and MVPA in ≥ 10-minute bouts on weekends were explained by adjustment for perceptions of neighbourhood quality (10%, 16% and 16%, respectively) than that for weekdays, which were reduced by 10%, 8% and 3% respectively (data not shown).

At follow-up

In total, 877 adults (69%) from 710 households were examined after 2 years; 441 (50%) had moved and were living in East Village at follow-up. Data were available at baseline and follow-up for 762 participants for physical activity outcomes and 822 participants for adiposity variables. There were no differences in age, sex or ethnic group between those followed up and not followed up (see *Report Supplementary Material 6*), although those followed up had slightly higher socioeconomic status and recorded more sedentary time at baseline than those not followed up.

Baseline characteristics for the 877 adults who were seen at follow-up are shown in *Table 6*, by housing sector and overall. In the social housing sector, age, sex, socioeconomic status and children in the household were similar for those living in East Village and for controls, although the East Village

TABLE 6 Baseline sociodemographic characteristics, physical activity and adiposity outcomes by housing sector for the control and East Village groups

				Housing sector								
	All housing sectors ($N = 877$)			Social ($N = 344$)			Intermediate ($N = 377$)			Market-rent ($N = 156$)		
Characteristic	Control ($N = 436$)	East Village ($N = 441$)	p-value[a]	Control ($N = 124$)	East Village ($N = 220$)	p-value[a]	Control ($N = 203$)	East Village ($N = 174$)	p-value[a]	Control ($N = 109$)	East Village ($N = 47$)	p-value[a]
Age (years)*, n *(%)												
16–24	75 (17)	104 (24)	0.01	18 (15)	47 (21)	0.27	30 (15)	38 (22)	< 0.001	27 (25)	19 (40)	0.07
25–34	185 (42)	194 (44)		32 (26)	61 (28)		100 (49)	113 (65)		53 (49)	20 (43)	
35–49	138 (32)	123 (28)		66 (53)	95 (43)		61 (30)	22 (13)		11 (10)	6 (13)	
≥ 50	38 (9)	20 (5)		8 (6)	17 (8)		12 (6)	1 (1)		18 (17)	2 (4)	
Sex*, n *(%)												
Female	248 (57)	247 (56)	0.79	91 (73)	158 (72)	0.75	107 (53)	70 (40)	0.02	50 (46)	19 (40)	0.53
Ethnic group*, n *(%)												
White	225 (52)	212 (48)	< 0.001	25 (20)	38 (17)	< 0.001	122 (60)	139 (80)	< 0.001	78 (72)	35 (74)	0.42
Black	81 (19)	131 (30)		40 (32)	120 (55)		32 (16)	9 (5)		9 (8)	2 (4)	
Asian	91 (21)	56 (13)		47 (38)	31 (14)		35 (17)	18 (10)		9 (8)	7 (15)	
Other	39 (9)	42 (10)		12 (10)	31 (14)		14 (7)	8 (5)		13 (12)	3 (6)	
NS-SEC*, n *(%)												
Higher managerial/ professional	246 (57)	179 (41)	< 0.001	24 (20)	23 (11)	0.12	146 (73)	124 (72)	0.01	76 (70)	32 (68)	0.53
Intermediate	54 (12)	69 (16)		16 (13)	27 (12)		22 (11)	34 (20)		16 (15)	8 (17)	
Routine/manual	44 (10)	56 (13)		26 (21)	46 (21)		13 (6)	10 (6)		5 (5)	0 (0)	
Economically inactive	89 (21)	133 (30)		57 (46)	121 (56)		20 (10)	5 (3)		12 (11)	7 (15)	

Characteristic	All housing sectors (*N* = 877)			Housing sector								
				Social (*N* = 344)			Intermediate (*N* = 377)			Market-rent (*N* = 156)		
	Control (*N* = 436)	East Village (*N* = 441)	*p*-value[a]	Control (*N* = 124)	East Village (*N* = 220)	*p*-value[a]	Control (*N* = 203)	East Village (*N* = 174)	*p*-value[a]	Control (*N* = 109)	East Village (*N* = 47)	*p*-value[a]
Children in household*, n *(%)												
Yes	172 (39)	203 (46)	0.05	109 (88)	178 (81)	0.09	52 (26)	21 (12)	< 0.001	11 (10)	4 (9)	1.00
Physical activity,[b] mean (SD)												
Total, *n*	405	403		112	199		189	164		104	40	
Daily steps	9192 (3284)	8644 (3104)	0.01	7707 (3069)	7730 (3345)	0.95	9639 (3224)	9592 (2584)	0.88	9980 (3128)	9304 (2468)	0.22
Daily MVPA (minutes)	61 (26)	58 (25)	0.06	50 (25)	50 (25)	0.97	63 (24)	66 (22)	0.31	70 (26)	65 (21)	0.32
Daily MVPA in ≥ 10-minute bouts (minutes)	22 (20)	19 (18)	0.02	12 (14)	12 (13)	0.85	23 (19)	25 (19)	0.45	30 (21)	28 (21)	0.70
Daily sedentary time (minutes)	588 (81)	583 (84)	0.36	544 (84)	545 (83)	0.91	598 (75)	617 (68)	0.01	616 (67)	627 (74)	0.42
Adiposity, mean (SD)												
Total, *n*	428	435		124	218		199	172		105	45	
BMI (kg/m^2)[c]	26 (5)	26 (6)	0.23	27 (5)	28 (7)	0.10	26 (5)	24 (4)	0.01	24 (4)	23 (3)	0.07
Fat mass per cent[d]	27 (10)	27 (11)	0.56	31 (10)	32 (11)	0.28	26 (9)	22 (8)	< 0.001	23 (9)	21 (8)	0.20

a Differences between control and East Village groups were tested using chi-squared or Fisher's exact test for demographic outcomes and *t*-tests for physical activity and adiposity outcomes.

b Physical activity outcomes were missing in the control and East Village groups, for 12 and 21 participants in the social housing sector, 14 and 10 participants in the intermediate housing sector and five and seven participants in the market-rent housing sector, respectively.

c BMI was missing in the control and East Village groups for zero and two participants in the social housing group, four and two participants in the intermediate housing sector and four and two participants in the market-rent housing sector, respectively.

d Percentage fat mass was missing in the control and East Village groups for one and five participants in the social housing sector, six and seven participants in the intermediate housing sector and five and two participants in the market-rent housing sector, respectively.

group had a higher proportion of participants of black African/Caribbean ethnic origin and a lower proportion of participants of Asian ethnic origin than the control group. In the intermediate sector, the East Village group were younger, less likely to be female, and more likely to be of white ethnicity, be economically active and have no children in the household than controls. In the market-rent sector, age, sex, ethnicity, socioeconomic status and children in the household were similar in the East Village and control groups. For housing sectors combined, the proportion of females in the two groups was similar, but participants in the East Village group were younger, more likely to be of black African–Caribbean ethnicity, less likely to be of Asian ethnicity and less likely to be in higher managerial/professional occupations than the control group. Overall, baseline daily steps and daily levels of MVPA were greater in the control group than in the East Village group, although differences by housing sector were less apparent. Although there was no overall difference in baseline adiposity levels, controls in the intermediate group had higher levels of BMI and fat mass percentage than those living in intermediate East Village accommodation. Those who had moved to East Village reported a sizable increase in scores for the perceptions of crime-free neighbourhood and higher quality neighbourhood at follow-up (*Table 7* and *Report Supplementary Material 7*). Compared with baseline data, participants living in East Village at follow-up lived closer to their nearest park, had better access to public transport and lived in a more walkable area (see *Table 7* and *Report Supplementary Material 7*).

The effect of moving to East Village on physical activity (daily steps, daily minutes of MVPA, daily sedentary time) and adiposity (BMI and percentage fat mass) is shown in *Table 8*, both overall and stratified by housing sector. Overall, there was weak evidence that moving to East Village was associated with a small increase in daily steps of 154 [95% confidence interval (CI) −231 to 539] after adjusting for sex, age group, ethnic group and housing sector. This appeared more pronounced in the intermediate sector (433 steps, 95% CI −175 to 1042 steps). There was also weak evidence of an increase in daily minutes of MVPA overall, both in total MVPA and in ≥ 10-minute bouts, in participants in the intermediate and market-rent sectors, and a decrease in daily minutes in participants in the social sector, although none of the effects were statistically significant. There was no evidence of a change in daily sedentary time, BMI or percentage fat mass, both overall and by housing sector (see *Table 8*). Inclusion of an interaction term between the East Village/control group and housing sector to allow for potential differential effects was not statistically significant ($p > 0.1$). Restricting analyses to 652 (86%) participants who recorded at least 4 days of ≥ 540 minutes accelerometry wear at baseline and at follow-up gave a larger effect for moving to East Village on daily steps (324 steps, 95% CI −93 to 741 steps; see *Report Supplementary Material 8*), but CIs still spanned the null value. There was weak evidence that the changes were larger at weekends (428 steps, 95% CI −288 to 1144 steps) than on weekdays (199 steps, 95% CI −223 to 620 steps), but CIs included the null value.

Separate analyses comparing change in daily steps in East Village participants with (1) controls who remained at their baseline address and (2) controls who moved elsewhere, allowed the effect of any move to be examined (see *Report Supplementary Material 8*). Although none of the differences were statistically significant, there was a suggestion of larger differences in daily steps when those in East Village were compared with those who had moved elsewhere [particularly in the intermediate housing sector where a difference of 677 steps (95% CI 15 to 1339 steps) was observed], with a smaller difference when compared with those who did not move. It is noteworthy that daily steps were marginally lower among those in the social sector who moved to East Village than those who moved elsewhere, but effect sizes were not statistically significant. There was no evidence of a difference after removing 21 women who reported being pregnant at baseline or follow-up. The missing data imputation analyses (adding a further 46 individuals at follow-up) gave similar results to the complete case analysis (see *Report Supplementary Material 9*).

TABLE 7 Within-person change (baseline to follow-up) in neighbourhood perception scores and built environment characteristics in control and East Village groups by housing sector and combined

	Housing sector											
	All housing sectors (*N* = 436)			Social (*N* = 124)			Intermediate (*N* = 203)			Market-rent (*N* = 109)		
Perceptions/characteristics	**Mean**	**95% CI**	***p*-value**	**Mean**	**95% CI**	***p*-value**	**Mean**	**95% CI**	***p*-value**	**Mean**	**95% CI**	***p*-value**
Neighbourhood perception scores[a]												
Control group												
Participants, *n*	436			124			203			109		
Crime score	0.6	0.2 to 1.0	0.004	1.2	0.4 to 2.1	0.004	0.1	−0.5 to 0.7	0.81	0.9	0.2 to 1.7	0.02
Quality score	0.7	0.3 to 1.2	< 0.001	1.3	0.5 to 2.0	0.001	0.5	−0.2 to 1.1	0.14	0.6	−0.2 to 1.4	0.15
East Village group												
Participants, *n*	441			220			174			47		
Crime score	4.6	4.1 to 5.1	< 0.001	5.6	4.9 to 6.3	< 0.001	3.8	3.2 to 4.4	< 0.001	2.7	1.2 to 4.3	< 0.001
Quality score	6.8	6.4 to 7.3	< 0.001	7.1	6.4 to 7.8	< 0.001	6.5	5.8 to 7.2	< 0.001	6.8	5.8 to 7.8	< 0.001
Built environment characteristics												
Control group												
Participants, *n*	376			120			178			78		
Distance to closest park (m)[b]	6	−37 to 49	0.79	−16	−72 to 39	0.56	10	−58 to 78	0.77	31	−83 to 144	0.59
Access to public transport (PTAL)[c]	−0.2	−0.3 to 0.0	0.07	−0.2	−0.5 to 0.0	0.07	−0.1	−0.4 to 0.2	0.411	−0.2	−0.6 to 0.2	0.45
Walkability[d]	0.3	0.1 to 0.5	0.01	−0.2	−0.5 to 0.2	0.34	0.6	0.2 to 1.0	0.005	0.4	−0.1 to 0.9	0.09
Land use mix[e]	0.02	0.00 to 0.04	0.05	−0.03	−0.05 to 0.00	0.04	0.04	0.01 to 0.07	0.005	0.03	−0.01 to 0.06	0.13
Residential density[f]	1.9	1.2 to 2.6	< 0.001	1.4	0.7 to 2.1	< 0.001	2.4	1.2 to 3.5	< 0.001	1.6	0.05 to 3.2	0.04
Street connectivity[g]	0.0	−0.1 to 0.1	0.89	−0.1	−0.3 to 0.1	0.17	0.1	−0.1 to 0.2	0.42	0.0	−0.3 to 0.2	0.89

continued

TABLE 7 Within-person change (baseline to follow-up) in neighbourhood perception scores and built environment characteristics in control and East Village groups by housing sector and combined (*continued*)

	Housing sector											
	All housing sectors (*N* = 436)			Social (*N* = 124)			Intermediate (*N* = 203)			Market-rent (*N* = 109)		
Perceptions/characteristics	Mean	95% CI	*p*-value	Mean	95% CI	*p*-value	Mean	95% CI	*p*-value	Mean	95% CI	*p*-value
East Village group												
Participants, *n*	414			216			160			38		
Distance to closest park (m)[b]	−525	−565 to −485	< 0.001	−477	−527 to −427	< 0.001	−570	−633 to −506	< 0.001	−614	−812 to −416	< 0.001
Access to public transport (PTAL)[c]	1.6	1.4 to 1.9	< 0.001	2.5	2.1 to 2.8	< 0.001	0.8	0.4 to 1.3	< 0.001	0.2	−0.7 to 1.0	0.66
Walkability[d]	2.5	2.2 to 2.7	< 0.001	2.8	2.5 to 3.0	< 0.001	2.2	1.7 to 2.6	< 0.001	2.1	0.6 to 3.7	0.01
Land use mix[e]	0.38	0.36 to 0.40	< 0.001	0.39	0.37 to 0.41	< 0.001	0.38	0.35 to 0.41	< 0.001	0.30	0.20 to 0.39	< 0.001
Residential density[f]	13.2	12.0 to 14.4	< 0.001	12.9	11.4 to 14.4	< 0.001	12.6	10.6 to 14.6	< 0.001	17.4	12.1 to 22.8	< 0.001
Street connectivity[g]	−0.9	−1.1 to −0.8	< 0.001	−0.8	−0.9 to −0.6	< 0.001	−1.1	−1.3 to −0.9	< 0.001	−1.1	−1.7 to −0.5	< 0.001

PTAL, public transport accessibility level.

a Neighbourhood perception scores from exploratory factor analysis on 14 neighbourhood perception items in the questionnaire. A higher score indicates perception of less crime and higher quality in the neighbourhood.

b Distance to closest park from choice of local, district and metropolitan parks.

c PTAL is a TfL score assessing the availability of public transport options. A high score indicates good public transport links.

d Walkability: the sum of three *z*-transformed variables: land use mix, residential density and street connectivity.

e Land use mix: the heterogeneity with which five functionally different land uses (residential, commercial, office, entertainment and institutional) are co-located in space. Values are normalised between 0 and 1, where 0 indicates single use and 1 indicates a perfectly even distribution of square footage across the different types of land use.

f Residential density: the number of residential units per km^2 of land devoted to residential use, including residential building footprint and attached gardens, expressed in 1000 residential units/km^2.

g Street connectivity: the number of intersections per kilometre of road.

TABLE 8 Effect of moving to East Village on physical activity and adiposity outcomes compared with controls, overall and by housing sector

	All housing sectors			Housing sector								
				Social			Intermediate			Market-rent		
	Difference	95% CI	*p*-value	Difference	95% CI	*p*-value	Difference	95% CI	*p*-value	Difference	95% CI	*p*-value
Physical activity outcomes	***(n = 762)***			***(n = 290)***			***(n = 335)***			***(n = 137)***		
Daily steps												
Model 1[a]	192	−173 to 557	0.30	−129	−728 to 469	0.67	500	−63 to 1063	0.08	160	−784 to 1105	0.74
Model 2[b]	235	−136 to 605	0.21	−187	−803 to 429	0.55	433	−175 to 1042	0.16	225	−730 to 1181	0.64
Model 3[c]	154	−231 to 539	0.43									
Total daily MVPA (minutes)												
Model 1[a]	0.5	−2.4 to 3.4	0.73	−1.7	−6.2 to 2.8	0.45	2.9	−1.4 to 7.3	0.19	1.1	−6.9 to 9.2	0.78
Model 2[b]	0.6	−2.3 to 3.5	0.67	−2.8	−7.4 to 1.9	0.24	1.7	−3.0 to 6.3	0.49	1.9	−6.3 to 10.0	0.65
Model 3[c]	0.2	−2.9 to 3.2	0.91									
Daily MVPA in ≥ 10-minute bouts (minutes)												
Model 1[a]	0.5	−1.8 to 2.7	0.67	−0.9	−3.8 to 2.0	0.55	3.1	−0.5 to 6.8	0.09	2.5	−4.0 to 9.0	0.45
Model 2[b]	0.6	−1.7 to 2.8	0.62	−1.2	−4.2 to 1.9	0.45	1.6	−2.3 to 5.4	0.43	3.1	−3.5 to 9.6	0.36
Model 3[c]	0.8	−1.5 to 3.1	0.48									
Daily sedentary time (minutes)												
Model 1[a]	−8	−18 to 2	0.12	−8	−28 to 11	0.39	−2	−17 to 12	0.77	3	−19 to 25	0.78
Model 2[b]	−8	−18 to 2	0.12	−13	−33 to 7	0.20	−4	−19 to 12	0.64	7	−15 to 29	0.54
Model 3[c]	−4	−15 to 7	0.45									

continued

TABLE 8 Effect of moving to East Village on physical activity and adiposity outcomes compared with controls, overall and by housing sector (*continued*)

	All housing sectors			Housing sector								
				Social			Intermediate			Market-rent		
	Difference	95% CI	*p*-value	Difference	95% CI	*p*-value	Difference	95% CI	*p*-value	Difference	95% CI	*p*-value
Adiposity outcomes	***(n = 822)***			***(n = 327)***			***(n = 358)***			***(n = 137)***		
BMI (kg/m²)												
Model 1[a]	0.3	0.0 to 0.5	0.06	0.4	−0.2 to 1.0	0.16	0.1	−0.2 to 0.5	0.54	0.2	−0.4 to 0.8	0.52
Model 2[b]	0.2	−0.1 to 0.5	0.14	0.2	−0.4 to 0.8	0.49	0.1	−0.3 to 0.5	0.66	0.2	−0.4 to 0.8	0.52
Model 3[c]	0.2	−0.1 to 0.5	0.25									
Percentage fat mass[d]												
Model 1[a]	0.1	−0.4 to 0.7	0.62	−0.1	−1.1 to 0.8	0.78	0.1	−0.6 to 0.8	0.81	0.3	−1.0 to 1.7	0.62
Model 2[b]	0.1	−0.4 to 0.7	0.58	−0.3	−1.3 to 0.7	0.60	0.2	−0.6 to 0.9	0.65	0.4	−1.0 to 1.8	0.58
Model 3[c]	0.1	−0.5 to 0.6	0.80									

a Model 1: adjusted for household as a random effect.
b Model 2: model 1 plus sex, age group and ethnic group as fixed effects.
c Model 3: model 2 plus housing sector as a fixed effect in the combined model.
d Fat mass per cent was missing for one participant in each of the social and intermediate housing sectors; $n = 820$ overall for percentage fat mass models.

Note
Model 1 adjusts for household as a random effect; model 2 adds sex, age group, ethnic group as fixed effects; model 3 adds housing sector as a fixed effect in the combined model.

Discussion

Baseline findings

The baseline findings from this study showed that, in the social housing sector, levels of physical activity were particularly low at weekends compared with weekdays, possibly reflecting higher occupational physical activity and lower leisure-time physical activity; weekday–weekend differences in physical activity were less marked among those seeking intermediate and market-rent housing. However, the lower registered time at weekends but higher MVPA and steps suggests more intense activity at weekends in the intermediate and market-rent housing sectors. Participants seeking social housing in East Village also had lower levels of physical activity and higher levels of BMI and percentage fat mass than those seeking intermediate and market-rent housing, even when adjusted for demographic factors.[70] Positive associations between perceived neighbourhood quality and physical activity, BMI and percentage fat mass at baseline were also shown. Adjustment for differences in perceived neighbourhood quality reduced the differences in physical activity and BMI by approximately 10% between social and intermediate housing sectors, equivalent to a reduction of 111 daily steps, 0.5 minutes of MVPA and 0.5 kg/m^2 BMI. However, a larger proportion of the difference in physical activity was apparent at weekends; equivalent to a reduction of 222 daily steps and 2.2 minutes of MVPA. These baseline findings provide further insight into the physical activity patterns of the ENABLE London cohort, and how moving to East Village might affect physical activity and adiposity levels in different socioeconomic groups.

Relation of baseline findings to previous studies

Previous studies have shown that lower socioeconomic status is associated with lower levels of physical activity,[71,72] and that those from more socially deprived backgrounds have the most barriers to being physically active.[8] Previous research examining the role of housing tenure is limited. Findings from this study showed marked differences in physical activity and adiposity between those seeking social, intermediate and market-rent housing. In particular, lower physical activity and higher adiposity were observed in participants seeking social housing, a group that comprises a high proportion of people from more socioeconomically disadvantaged backgrounds.[61] The higher levels of BMI and percentage fat mass in those seeking social housing than in those seeking intermediate or market-rent housing is consistent with systematic reviews that have found an association between lower socioeconomic status and higher levels of adiposity, particularly in higher income countries and among women.[73] Although socioeconomic status is a strong determinant of housing status, to our knowledge this is the first study to explicitly examine housing sector differences in objectively measured physical activity and markers of adiposity levels (i.e. BMI and percentage fat mass). However, it is important to appreciate more broadly what these aspirational housing sector differences might represent before considering what change in the residential built environment might do. Related studies have shown that those in social housing are less likely to use active travel than owner occupiers,[19] and that those in social housing and home owners with a mortgage are more likely to be obese and have higher levels of illness and disability than outright home owners, even after adjustment for other socioeconomic status markers.[74] These findings suggest that the effect of home ownership may be more complex and cannot be simply explained by socioeconomic status. Neighbourhood quality may offer a partial explanation for these findings.[75] Baseline findings from this study showed that perceptions of better neighbourhood quality were associated with physical activity whereas perceptions of crime were not. In contrast, a large UK-based study found that perceptions of feeling safe in the neighbourhood had the largest effect on levels of physical activity compared with perceptions of leisure facilities, a sense of belonging or access to public transport or amenities.[76] Another study in the USA found that low perceived safety from crime was associated with lower levels of MVPA.[77] However, a recent review concluded that higher-quality evidence is needed, including from prospective studies and natural experiments in areas of wide crime variability, to further understand the effect of crime on physical and mental health.[28] Moreover, previous work has suggested that objective and perceived measures of the built environment correlate differently with physical activity levels, suggesting that these measures are assessing different dimensions of the built environment, which relate differently to health behaviour.[78]

The baseline findings showed that physical activity levels were particularly low at the weekend among those seeking social housing, which is consistent with findings from a systematic review which found that leisure-time physical activity (which may be more likely to take place at weekends) was lower among those from lower socioeconomic groups.[9] This suggests that low-cost strategies to increase weekend physical activity may be particularly beneficial to more disadvantaged households. A free community-based programme in Bogotá, Colombia, temporarily closed streets on Sundays to encourage physical activity among more disadvantaged local residents.[79] A similar programme has been trialled in the USA;[80] however, the effectiveness, longevity and generalisability of these programmes to other socioeconomically deprived areas is yet to be established.

The baseline findings from the ENABLE London cohort suggest that perceived neighbourhood quality is associated with meaningful differences in physical activity and markers of adiposity. Differences in steps (680 steps) and BMI (3.6 kg/m^2) between the lowest and highest quintiles of perceived neighbourhood quality should be considered in the context of an average of 10,000 steps per day, where a 5% increase (500 steps) would be a worthwhile population-level increase and a 5 kg/m^2 increase in BMI would be associated with a 31% increase in all-cause mortality.[81] Hence, improvements in neighbourhood quality could be associated with health benefits that are of public health importance. There were also substantial differences in physical activity, BMI and percentage fat mass between the three housing sectors studied. In particular, the very low levels of physical activity in the social housing sector during the weekend could provide a target for intervention to increase levels of physical activity; again, these differences should be considered in relation to 500 steps per day, which can be considered as an increase of population importance. Perceptions of neighbourhood quality reduced baseline differences in physical activity and adiposity between housing sector groups, and the measurement of more objective markers of neighbourhood quality has the potential to explain more.[78]

Follow-up findings

Compared with pre-move residential areas, East Village was assessed as a more walkable place with greater access to public transport and closer proximity to parks, and was perceived as having marked improvements in neighbourhood quality. Despite this, at 2-year follow-up there was weak evidence that moving to East Village was associated with an overall increase in daily steps compared with not moving. This increase was the largest in those who moved into intermediate housing, whereas those in social housing showed a small decline in their physical activity. Overall increases in time spent in MVPA daily and decreases in daily sedentary behaviour were also observed, but again effects were small. There were no changes in markers of adiposity associated with moving to East Village, either overall or by housing tenure.

Change in the built environment

A key issue is whether or not the change in the built environment, in this case East Village, 'the intervention', is sufficient and rapid enough to observe changes in health behaviour,[33,82] and whether or not the correct components of the built environment to maximise physical activity were present.[41,83] East Village includes a multitude of features that could plausibly have a beneficial effect on the physical activity patterns of occupants.[61] These include more equitable access to improved public transport and active travel opportunities.[42,43] East Village is also situated close to leisure-time physical activity-permissive features, including parkland, street furniture and pedestrianised areas, as well as major sporting facilities. It is also situated within walking distance of retail outlets.[42,43] Hence, collectively, East Village has a multitude of activity-permissive features, which could plausibly increase physical activity levels by encouraging time spent outdoors.[84,85] Differences in the built environment of East Village were evident by the substantial changes in objective GIS measures of the built environment (including increased walkability, access to public transport and parks) and the sizeable improvements in neighbourhood perceptions observed among residents, especially those from the social housing sector. This raises the question of why larger improvements in physical activity were not observed.

Relation of follow-up findings to previous studies

Previous research has shown cross-sectional associations between attributes of the built environment and physical activity,[32,86,87] whereas prospective studies from fewer housing relocation or neighbourhood change studies have shown more modest effects.[33] To our knowledge, the ENABLE London study is the first longitudinal study to use objective measures of physical activity in a cohort relocating to a new neighbourhood designed for healthy active living, rather than relying solely on less reliable self-report.[88] Steps were chosen a priori as the primary outcome given the focus of examining the effect of changing to active design principles, and hence walkability of the built environment.[61] We are not aware of any other longitudinal studies with a directly comparable outcome. Despite this, some broad comparisons with other longitudinal studies are possible. Although increases in active modes of travel have been observed in these studies (particularly in reported cycling and use of public transport),[89–91] change in overall self-reported walking and physical activity levels have been less apparent.[82,92,93] However, change in physical activity may be more nuanced. The RESIDential Environment (RESIDE) study recruited 1800 people who moved into new homes in Perth, Australia, and, although there were no overall differences in self-reported physical activity, increases in recreational walking and opposing decreases in transport-related walking were evident.[94] These differences were attributed to an increase in access to recreational facilities (e.g. parks, sports fields and beaches) and a decrease in access to transport (within a 15-minute walk), respectively.[95]

Use of the residential built environment may differ throughout the week. We observed appreciable differences in weekday versus weekend physical activity across housing sectors within this cohort at baseline.[70] Although prospective findings from this study also indicated increased steps at weekends compared with weekdays was associated with moving to East Village (i.e. 428 vs. 199 steps), these differences were both consistent with no effect (i.e. CIs included the null value of zero steps).

Conclusions

Teasing out the causal relationship between the built environment and health behaviours is complex,[96] and the reasons for failing to observe clear effects in this longitudinal study when cross-sectional findings are less equivocal remain unclear.[33] Some systematic reviews have avoided this issue by simply excluding longitudinal or experimental studies, which raise concerns that such reviews lead to greater certainty about biased findings,[97–100] especially when those living in better neighbourhoods, with built environments more conducive to physical activity, may be fundamentally different from those who do not. However, it is notable that longitudinal studies may also be prone to selection bias, whereby those who choose to move to better neighbourhoods have different health behaviours from those who choose to remain. The ENABLE London study sought to minimise these effects by recruiting a cohort that was seeking to move before any move to East Village, where half of whom moved to East Village and the other half of whom did not. Further consideration of the strengths and limitations of the ENABLE London study and the potential implications of the findings are considered in *Chapter 9*.

Chapter 4 Residential built environment and physical activity: cross-sectional and longitudinal analyses

Introduction

In this chapter we focus on exploring whether or not there are associations between objectively measured features of the built environment and physical activity at baseline and whether or not changes in the built environment are associated with changes in physical activity.

Physical activity is a protective factor for a wide range of physical and psychological disorders.[1,6,101] The current population levels of physical activity are too low both in the UK and globally,[102] and individuals from more disadvantaged socioeconomic groups are less physically active, in terms of both daily steps[70] and MVPA.[17,103] In recent years, epidemiological research has increasingly incorporated socioecological models that acknowledge the role of the built environment in determining physical activity behaviours.[104] Researchers have hypothesised that a deprivation amplification effect exists,[105] whereby disadvantaged individuals have greater exposure to less health-promoting neighbourhood environments.[106–109] Policies aimed at modifying built environment factors have been promoted as potential levers for reducing socioeconomic inequalities in health behaviours, including physical activity. However, the extent to which differences in residential built environment factors contribute to individual socioeconomic inequalities in physical activity remains uncertain.

In the UK, environmental factors that have been found to be positively associated with higher physical activity levels include greater neighbourhood walkability,[110] improved accessibility to green space[32,111] and improved accessibility to public transport.[32] However, these findings rely on a limited number of studies. This evidence is also mixed, with, for instance, both positive[32,111] and null[112] associations found between accessibility to green space and physical activity. More work is needed to establish whether or not specific features of the residential built environment shape physical activity behaviours in the UK, and whether or not differences in the accessibility of these features contribute to socioeconomic differences in physical activity.

Associations between residential physical activity facilities and physical activity have been shown to vary by time of the day and day of the week.[113] Daily variations in the number of steps and minutes of MVPA have been reported, with more physical activity on weekdays than at weekends.[70,114,115] Time use studies show that week and weekend days markedly differ in terms of human activity, with the former focused more on work and the latter more on leisure and recreational activities.[116] Use of the residential built environment may, therefore, be expected to be different at weekdays and weekends. This suggests that we should take into account weekday and weekend variations in physical activity when seeking to better understand the contribution of the residential built environment to physical activity.[117]

Many of these studies rely on cross-sectional designs and are therefore prone to biases, such as residential self-selection.[118] As environments can change in response to residents' preferences and residents may choose to live in locations consistent with their preferred lifestyles, cross-sectional designs limit our ability to make causal inferences. Longitudinal studies that examine associations between time-varying features of the residential built environment and physical activity are needed to strengthen evidence for a causal effect. Natural experiments of changes to the built environment could help generate better 'causal' evidence that environmental factors are important for physical activity.[119]

Aims

In this chapter we assess whether or not:

1. the residential built environment is associated with the number of daily steps walked and the total daily minutes of MVPA accumulated on weekdays and at the weekend
2. associations between the residential built environment and physical activity levels are modified by socioeconomic status
3. the distribution of residential built environment factors differs by socioeconomic status, and, if so, whether or not this contributes to socioeconomic differences in the number of daily steps and the time in MVPA on weekdays and at the weekend
4. changes in exposure to features of the residential built environment can predict changes in physical activity levels among adult participants and whether or not these effects differ by socioeconomic status.

Methods

In this chapter we use baseline and follow-up measurements of adult physical activity and sociodemographic data before and after relocation into East Village.

Baseline data

Of the 1278 study participants, we excluded those who lived outside Greater London ($n = 81$) and those without sufficient accelerometer data (at least 9 hours for at least 1 day is sufficient) on either weekdays or weekends ($n = 144$) (some participants fit multiple exclusion categories). Those who were excluded from the analytical sample had similar characteristics to those included in the sample in terms of housing status ($p = 0.17$), age ($p = 0.27$), sex ($p = 0.06$) and ethnicity ($p = 0.18$) (see *Report Supplementary Material 10*). Of the 1064 participants retained for analyses, 442 were seeking relocation into social, 436 into intermediate and 186 into market-rent accommodation; 1053 participants had physical activity data on weekdays, 848 on weekends and 837 on both weekdays and weekends. To maximise power to detect associations and reduce selection bias, analyses were performed with the maximum number of participants available (i.e. 1053 individuals in analyses on physical activity on weekdays and 848 individuals in analyses on physical activity at weekends). Sensitivity analyses were performed on the subset of 837 participants who had data on both weekdays and weekends.

Follow-up data

Of the 877 participants followed up (69%), those who lived outside Greater London at either baseline or follow-up and those who did not have physical activity data at baseline or follow-up ($n = 190$) were excluded. Those excluded from the analytical sample had similar characteristics to those included with regard to sex ($p = 0.36$) and ethnicity ($p = 0.76$), but were younger ($p = 0.009$) and had more intermediate and less market-rent seekers compared with those included ($p = 0.003$) (see *Report Supplementary Material 11*). A total of 687 participants were retained for analyses; 680 participants had physical activity data on weekdays and 517 on weekend days, both at baseline and at follow-up. Of the 687 participants, 283 were seeking relocation into social housing, 301 into intermediate housing, and 103 into market-rent accommodation.

Primary outcomes

Accelerometer-derived physical activity

Mean daily steps and mean daily time (minutes) spent in MVPA were collected from accelerometer data among those who wore the device for at least 9 hours per day for at least 1 day. Daily steps were adjusted for day of the week, day order of recording and month of accelerometer data collection.[70] Mean daily steps and mean daily time spent in MVPA specifically on weekdays and at weekends were derived.

Environmental exposures

Participants were geocoded to the centroid of the footprint of their building of residence, using OS AddressBase Premium (versions 2015 and 2017 for geocoding at baseline and at follow-up, respectively) to match participants' declared residential addresses with XY coordinates. Residential locations were then used to derive a range of built environment factors that were hypothesised to be associated with physical activity, as follows.

Residential neighbourhood walkability

Walkability scores were calculated by summing the *z*-scores of the three following GIS-derived variables aggregated within a 1-km street network home-centred buffer: (1) street connectivity, as the number of junctions of three or more road branches per street-kilometre, (2) land use mix, as the evenness of distribution of square footage of residential, commercial, office, entertainment and institutional building footprints, based on existing literature[52,110] and (3) net residential density, as the unique number of residential addresses per squared kilometre of building footprint devoted to residential use (i.e. residential building and attached gardens) (see *Report Supplementary Material 12*). Both baseline and follow-up *z*-score transformations were based on the mean and standard deviation of the baseline sample, as has been done previously.[89] Rescaling scores at follow-up using the baseline population sample estimates ensured comparability of scores both across participants and across time for the same participant, hence providing a meaningful quantification of the change of walkability over time. Land use mix and net residential density variables were log-transformed to fit a comparable scale. The choice of 1-km street network home-centred buffers was motivated by two considerations. First, destinations that are within 1 km (a 15-minute walk) from home have been defined as reachable by foot in the literature.[120] In the absence of more personalised measures of the residential neighbourhood, 1 km was, thus, judged as a reasonable aggregation unit to encompass the opportunities available in the residential area of each participant. Second, a 1-km buffer has been used in many studies that found significant associations between features of the built environment and physical activity outcomes.[121,122]

Proximity from home to parks

Using data from Greenspace Information for Greater London (GiGL),[123] proximity to three types of park – 'metropolitan', 'district' and 'local' – was calculated on the basis of street network distance from the home address to the nearest entrance for each park type. Park type is derived from the Greater London Authority London Plan, March 2016,[124] and is based on park size and the number and type of facilities a park provides. 'Metropolitan' parks are the largest and have the most amenities, and 'local' parks are the smallest and are the least well-equipped of these three types (see *Report Supplementary Material 13*). Where there were missing entrance points to parks in the GiGL database ($n = 22$, 2.9%), they were manually geocoded based on visual data drawn from Google Maps (Google Inc., Mountain View, CA, USA).

Public transport accessibility

Each ENABLE London participant was assigned a public transport accessibility level (PTAL) score based on the closest location of public transport to their place of residence where a PTAL value was made available by TfL, the local government body responsible for the transport system in Greater London. PTAL is an averaged measure of the densities of the London public transport access points (trains, buses, underground, Docklands Light Railway, trams) and also accounts for the frequency of service. It is available for the centroid of each 100 m × 100 m cell of a grid covering the whole of Greater London and is expressed as a nine-category variable (lower scores reflecting poorer accessibility). The nine PTAL categories were collapsed into three categories (low: PTAL scores 0, 1a, 1b; intermediate: PTAL scores 2, 3, 4; high: PTAL scores 5, 6a, 6b) to increase the number of participants per category, especially for those residing in areas with the lowest accessibility scores.

Data sources and versions used for computing these environmental variables are detailed in *Report Supplementary Material 14*.

Covariates

Covariates included sex (female, male), age group (16–24, 25–34, 35–49 and ≥ 50 years), ethnicity (white, black, Asian, mixed/other) and aspirational housing tenure being sought (social, intermediate, market-rent). Seekers of intermediate accommodation were used as the reference group, as this group had the largest number of participants.

Household income, occupational status, presence of children in the household and education level were highly correlated to aspirational housing status, hence, these variables were not adjusted for in the final regression models to avoid overadjustment (see *Report Supplementary Material 15*). Other hypothesised covariates, including car use and attitude towards physical activity, were excluded after initial consideration, as they were not found to be associated with exposures and outcomes in bivariate analyses or their addition to fully adjusted models did not appreciably alter coefficients.

Statistical analyses

All analyses were carried out using Stata Special Edition version 15 for Windows.

Analyses of baseline data

First, aspirational housing tenure differences in sociodemographic characteristics, residential built environment factors (i.e. walkability, distance to parks and accessibility to public transport) and daily steps and MVPA (minutes) were examined. Chi-squared tests were used to assess the differences between housing tenure for sociodemographic characteristics and public transport availability (PTAL score). Analysis of variance was used to assess differences between housing tenure for the residential built environment and physical activity variables. Second, multilevel linear regression models, including a random effect to allow for clustering at baseline household level, were used to assess whether or not environmental variables were associated with the daily steps taken overall, on weekdays and at weekends separately. Environmental variables were examined both separately (i.e. entered in turn in the models) and concomitantly (to examine their independent association). All models were adjusted for clustering at baseline household level, sex, age group, ethnicity and aspirational housing tenures as fixed effects and household as a random effect to allow for clustering at baseline household level. We also examined whether or not effects of environmental variables on physical activity behaviour differed by aspirational housing tenure. MVPA in 10-minute bouts was not used, as most participants had none or low values and no transformation would have permitted easy interpretation of the regression coefficients. Third, where environmental factors showed significant associations with the number of daily steps, multilevel regression models further examined whether or not housing tenure differences in physical activity were attenuated after adjustment for environmental factors.

Analyses of follow-up data

First, changes in neighbourhood walkability, residential density, land use mix, street connectivity, distance to a park and accessibility to public transport were quantified in the whole sample and by housing sector, and differences between housing sectors were assessed using analysis of variance. Second, multilevel linear regression models were fitted to examine the effect of changes in exposure to residential built environment features on changes in total daily steps and total daily MVPA (minute) (one model per residential built environment exposure variable and per physical activity outcome). Average daily steps (daily MVPA) at follow-up were regressed on average daily steps (daily MVPA) at baseline, adjusting for a change in exposure as a fixed effect and baseline household as a random effect to allow for household clustering. Models with further adjustment for sex, age group and ethnic group were also fitted. In addition, the same outcomes were examined separately for both weekdays and weekend days. Finally, an interaction term between each change in environmental exposure (taken in turn) and housing sector was included.

Results

Associations between the built environment and physical activity at baseline

Descriptive analyses

Baseline descriptive statistics are shown in *Table 9*. Females constituted 58% of the analytical sample, which was largely white (48%). Women, older people and those belonging to ethnic minorities were more prevalent among social housing seekers than among intermediate and market-rent housing seekers ($p < 0.001$); the sociodemographic characteristics of intermediate and market-rent housing seekers were similar. Participants seeking relocation to social housing were less physically active, with 9.4% (social: 8618 steps, 95% CI 8247 to 8990 steps; intermediate: 9516 steps, 95% CI 9170 to 9862 steps) and 25.3% (social: 6909 steps, 95% CI 6390 to 7428 steps; intermediate: 9385 steps, 95% CI 8925 to 9846 steps) fewer steps on weekdays and at weekends, respectively, than participants seeking intermediate housing. Social housing seekers also resided in less walkable areas, according to walkability score, than intermediate housing seekers (social: −0.51, 95% CI −0.70 to −0.31; intermediate: 0.21, 95% CI −0.05 to 0.46); lived further away (median km) from metropolitan parks [social: 2.53 km, interquartile range (IQR) 1.43–3.71 km; intermediate: 1.90 km, IQR 0.95–2.99 km]; were closer (median km) to their nearest local park than intermediate housing seekers (social: 0.62 km, IQR 0.38–0.98 km; intermediate: 0.88 km, IQR 0.48–1.35 km); and had poorer accessibility to public transport (22.9% had high accessibility compared with 41.3% for intermediate housing seekers).

Participants seeking relocation to market-rent housing had a similar level of physical activity to participants seeking intermediate housing in both daily steps and MVPA accumulated both on weekdays and at weekends. Participants seeking market-rent housing also resided in more walkable areas according to walkability score (market-rent: 0.94, 95% CI 0.48 to 1.40; intermediate: 0.21 95% CI −0.05 to 0.46), but both groups lived at a similar distance to their closest metropolitan, district and local parks, and had similar accessibility to public transport.

Associations between built environment and physical activity

The associations between built environment factors and the number of daily steps and amount of MVPA taken on weekdays and at weekends are presented in *Table 10*, and displayed graphically in *Report Supplementary Material 16*.

Weekdays

In models adjusted for sociodemographic characteristics, both daily steps taken and MVPA accumulated were negatively associated with the distance from home to the closest metropolitan park [mean difference in daily steps (−206 steps, 95% CI −354 to −58 steps); mean difference in daily minutes of MVPA (−1.8 minutes, 95% CI −2.9 to −0.5 minutes) per kilometre of distance to the closest metropolitan park], indicating that the more distant the metropolitan park, the smaller the overall number of steps taken and the shorter the time spent in MVPA (*Figure 4*), particularly among those from intermediate and market-rent tenured groups (see *Figure 4*). Associations between accessibility to public transport and daily steps and MVPA were borderline statistically significant in models adjusted for sociodemographic characteristics (mean differences in daily steps: 767 steps, 95% CI −12 to 1546 steps; mean difference in daily minutes of MVPA: 5.8 minutes, 95% CI −0.3 to 11.9 minutes for those with low accessibility compared with those with high accessibility), and reached statistical significance after further adjustment for the other residential built environmental factors (mean differences in daily steps: 1186 steps, 95% CI 296 to 2076 steps; mean difference in daily minutes of MVPA: 9.7 minutes, 95% CI 2.7 to 16.6 minutes). Adjustment for other residential built environmental factors, however, led to an inflation of the regression estimate and a widening of the CI compared with models adjusting only for sociodemographic characteristics, raising potential multicollinearity issues.

TABLE 9 Baseline sociodemographic and daily steps of the ENABLE London participants by aspirational housing tenure

Characteristic	All housing sectors	Housing sector			*p*-value[a]
		Social	Intermediate	Market-rent	
Total participants, *n* (%)	1064 (100)	442 (42)	463 (44)	186 (17)	
Sociodemographics*, n *(%)					
Sex: female	621 (58)	330 (75)	210 (48)	81 (44)	< 0.001
Age group (years)					
16–24	222 (21)	95 (21)	77 (18)	50 (27)	< 0.001
25–34	464 (44)	112 (25)	254 (58)	98 (53)	
35–49	310 (29)	198 (45)	92 (21)	20 (11)	
≥ 50	68 (6)	37 (8)	13 (3)	18 (10)	
Ethnicity					
White	511 (48)	83 (19)	301 (69)	127 (68)	< 0.001
Black	270 (25)	210 (48)	46 (11)	14 (8)	
Asian	172 (16)	90 (20)	61 (14)	21 (11)	
Mixed/other	111 (10)	59 (13)	28 (6)	24 (13)	
Physical activity facilities in the residential area					
Walkability, mean (95% CI)	0.04 (−0.12 to 0.20)	−0.51 (−0.70 to −0.31)	0.21 (−0.05 to 0.46)	0.94 (0.48 to 1.40)	< 0.001
Street connectivity, mean (95% CI)	8.7 (8.6 to 8.7)	8.5 (8.4 to 8.6)	8.7 (8.6 to 8.8)	9.0 (8.8 to 9.2)	< 0.001
Residential density (1000 habitants/km^2), mean (95% CI)	12.2 (11.9 to 12.6)	10.3 (9.9 to 10.7)	13.1 (12.5 to 13.8)	14.8 (13.8 to 15.9)	< 0.001
Land use mix, mean (95% CI)	0.38 (0.37 to 0.39)	0.34 (0.33 to 0.36)	0.39 (0.37 to 0.41)	0.46 (0.43 to 0.49)	< 0.001
Distance to metropolitan parks (km), mean (IQR)	2.2 (1.2–3.5)	2.5 (1.4–3.5)	1.9 (0.9–3.5)	1.9 (1.0–3.5)	< 0.001
Distance to district parks (km), mean (IQR)	2.2 (1.4–3.1)	2.4 (1.7–3.1)	2.0 (1.1–3.1)	2.0 (1.4–3.1)	< 0.001
Distance to local parks (km), mean (IQR)	0.7 (0.4–1.2)	0.6 (0.4–1.2)	0.9 (0.5–1.2)	0.9 (0.5–1.2)	< 0.001
Public transport accessibility (PTAL score)*, n *(%)					
Low	96 (9)	47 (11)	37 (8)	12 (6)	
Intermediate	606 (57)	294 (67)	219 (50)	93 (50)	
High	362 (34)	101 (23)	180 (41)	81 (44)	
Physical activity*,[b] *mean (95% CI)					
Daily steps on weekdays	9126 (8919 to 9333)	8618 (8247 to 8990)	9516 (9170 to 9862)	9409 (8895 to 9923)	0.005
Daily steps on weekend days	8448 (8170 to 8725)	6909 (6390 to 7428)	9385 (8925 to 9846)	9540 (8874 to 10,206)	< 0.001
Daily minutes of MVPA on weekdays	61 (59 to 63)	57 (54 to 60)	63 (61 to 66)	66 (62 to 70)	0.001
Daily minutes of MVPA on weekend days	55 (53 to 58)	46 (41 to 50)	61 (57 to 65)	64 (59 to 70)	< 0.001

a Differences between housing sectors were tested using chi-squared (sex, age, ethnicity, PTAL), analysis of variance (walkability, street connectivity, residential density, land use mix), Kruskal–Wallis analysis of variance (distances to parks), and Wald test (physical activity outcomes).
b Physical activity outcomes were available for 1053 participants on weekdays and for 848 participants on weekend days.

TABLE 10 Regression estimates for the baseline associations of daily steps and MVPA with residential built environment factors

Residential built environment factors	Model 1[a] β (95% CI)	Model 2[b] β (95% CI)	Model 3[c] β (95% CI)	Model 1[a] β (95% CI)	Model 2[b] β (95% CI)	Model 3[c] β (95% CI)
	Daily steps on weekdays (n = *1053*)			*Daily steps on weekends* (n = *848*)		
Walkability	52 (−30 to 134)	−5 (−86 to 76)	38 (−57 to 132)	255 (139 to 371)[d]	135 (28 to 242)[d]	144 (19 to 269)[d]
Street connectivity	48 (−132 to 228)	−39 (−215 to 137)	–	322 (63 to 582)[d]	156 (−79 to 391)	–
Residential density (1000 habitants/km^2)	41 (5 to 76)[d]	5 (−31 to 41)	–	129 (78 to 179)[d]	51 (3 to 99)[d]	–
Land use mix	498 (−644 to 1641)	−291 (−1419 to 837)	–	3520 (1884 to 5156)[d]	1547 (34 to 3061)[d]	–
Distance to closest metropolitan park (km)	−294 (−446 to −143)[d]	−206 (−354 to −58)[d]	−264 (−422 to −107)[d]	−363 (−582 to −144)[d]	−125 (−323 to 74)	−144 (−354 to 66)
Distance to closest district park (km)	−93 (−265 to 79)	7 (−160 to 174)	−64 (−240 to 113)	−370 (−617 to −124)[d]	−180 (−402 to 42)	−138 (−372 to 96)
Distance to closest local park (km)	170 (−174 to 514)	−84 (−420 to 253)	−185 (−529 to 158)	1147 (669 to 1624)[d]	597 (161 to 1032)[d]	598 (155 to 1040)[d]
Accessibility to public transport						
Low	442 (−362 to 1247)	767 (−12 to 1546)	1186 (296 to 2076)[d]	−1352 (−2516 to −187)[d]	−608 (−1657 to 442)	60 (−1136 to 1256)
Intermediate	−481 (−948 to −15)[d]	−152 (−609 to 305)	8 (−487 to 503)	−1128 (−1803 to −453)[d]	−364 (−981 to 252)	−8 (−670 to 654)
High	–	–	–	–	–	–

continued

TABLE 10 Regression estimates for the baseline associations of daily steps and MVPA with residential built environment factors (*continued*)

Residential built environment factors	Model 1[a] β (95% CI)	Model 2[b] β (95% CI)	Model 3[c] β (95% CI)	Model 1[a] β (95% CI)	Model 2[b] β (95% CI)	Model 3[c] β (95% CI)
	Daily MVPA (minutes) on weekdays (n = *1053*)			*Daily MVPA (minutes) on weekends* (n = *848*)		
Walkability	0.7 (−0.0 to 1.3)	0.1 (−0.6 to 0.6)	0.4 (−0.3 to 1.2)	2.2 (1.2 to 3.1)[d]	1.2 (0.3 to 2.1)[d]	1.4 (0.4 to 2.5)[d]
Street connectivity	0.6 (−0.9 to 2.0)	−0.3 (−1.7 to 1.0)	–	2.7 (0.6 to 4.8)[d]	1.3 (−0.6 to 3.2)	–
Residential density (1000 habitant/km^2)	0.4 (0.1 to 0.7)[d]	0.0 (−0.2 to 0.3)	–	1.1 (0.7 to 1.5)[d]	0.4 (0.0 to 0.8)[d]	–
Land use mix	9.1 (0.0 to 18.2)[d]	1.3 (−7.5 to 10.1)	–	32.1 (18.9 to 45.2)[d]	16.8 (4.6 to 29.0)[d]	–
Distance to closest metropolitan park (km)	−2.5 (−3.7 to −1.3)[d]	−1.8 (−2.9 to −0.5)[d]	−2.1 (−3.4 to −0.9)[d]	−2.9 (−4.7 to −1.2)[d]	−1.1 (−2.7 to 0.4)	−1.2 (−2.9 to 0.5)
Distance to closest district park (km)	−0.6 (−2.0 to 0.7)	0.3 (−1.0 to 1.6)	−0.2 (−1.5 to 1.2)	−2.4 (−4.4 to −0.4)[d]	−0.9 (−2.7 to 0.9)	−0.4 (−2.3 to 1.4)
Distance to closest local park (km)	2.0 (−0.8 to 4.7)	−0.3 (−3.0 to 2.3)	−1.0 (−3.7 to 1.6)	9.0 (5.2 to 12.9)[d]	4.7 (1.2 to 8.2)[d]	4.9 (1.3 to 8.5)[d]
Accessibility to public transport						
Low	2.7 (−3.7 to 9.1)	5.8 (−0.3 to 11.9)	9.7 (2.7 to 16.6)[d]	−9.5 (−18.9 to −0.1)[d]	−4.0 (−12.5 to 4.5)	2.7 (−7.0 to 12.4)
Intermediate	−4.5 (−8.2 to −0.8)[d]	−1.7 (−5.3 to 1.8)	−0.2 (−4.1 to 3.6)	−8.2 (−13.7 to −2.7)[d]	−2.7 (−7.6 to 2.3)	0.7 (−4.7 to 6.0)
High	–	–	–	–	–	–

a Model 1 adjusts only for clustering at household level (referred to as 'minimally adjusted model' in the text).
b Model 2 adjusts for sex, age group, ethnic group, aspirational housing tenure and clustering at household level.
c Model 3 adjusts for sex, age group, ethnic group, aspirational housing tenure, clustering at household level and environmental variables entered simultaneously.
d β coefficient is statistically significant at $p < 0.05$.

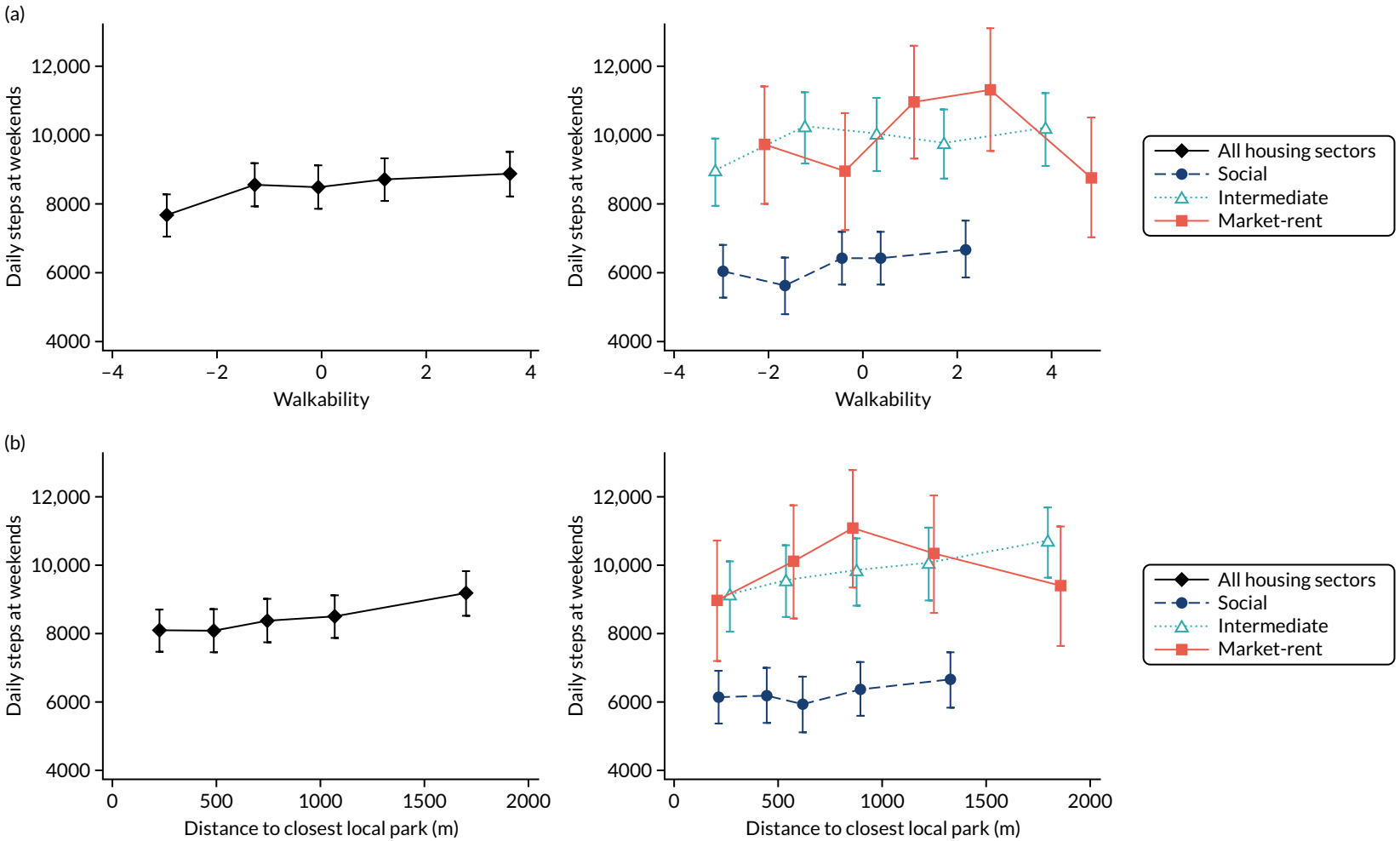

FIGURE 4 Daily steps and MVPA (mean and 95% CI) by quintile of selected residential built environmental factors, overall and by housing sector. (a) Daily steps at weekends and walkability; (b) daily steps at weekends and distance to closest local park; (c) daily steps on weekdays and distance to closest metropolitan park; (d) daily MVPA at weekends and walkability; (e) daily MVPA at weekends and distance to closest local park; and (f) daily MVPA on weekdays and distance to closest metropolitan park. Notes: mean daily steps (95% CI) at weekends or on weekdays are plotted against median value of quintile of built environment variable, for all housing sectors combined and by housing sector. Daily steps are adjusted for sex, age group, ethnic group as fixed effects and household as a random effect in a multilevel model. Daily steps for all housing sectors are additionally adjusted for housing sector as a fixed effect. Footnotes: mean daily MVPA (95% CI) at weekends or on weekdays is plotted against median value of quintile of built environment variable, for all housing sectors combined and by housing sector. Daily MVPA is adjusted for sex, age group, ethnic group as fixed effects and household as a random effect in a multilevel model. Daily MVPA for all housing sectors is additionally adjusted for housing sector as a fixed effect. (*continued*)

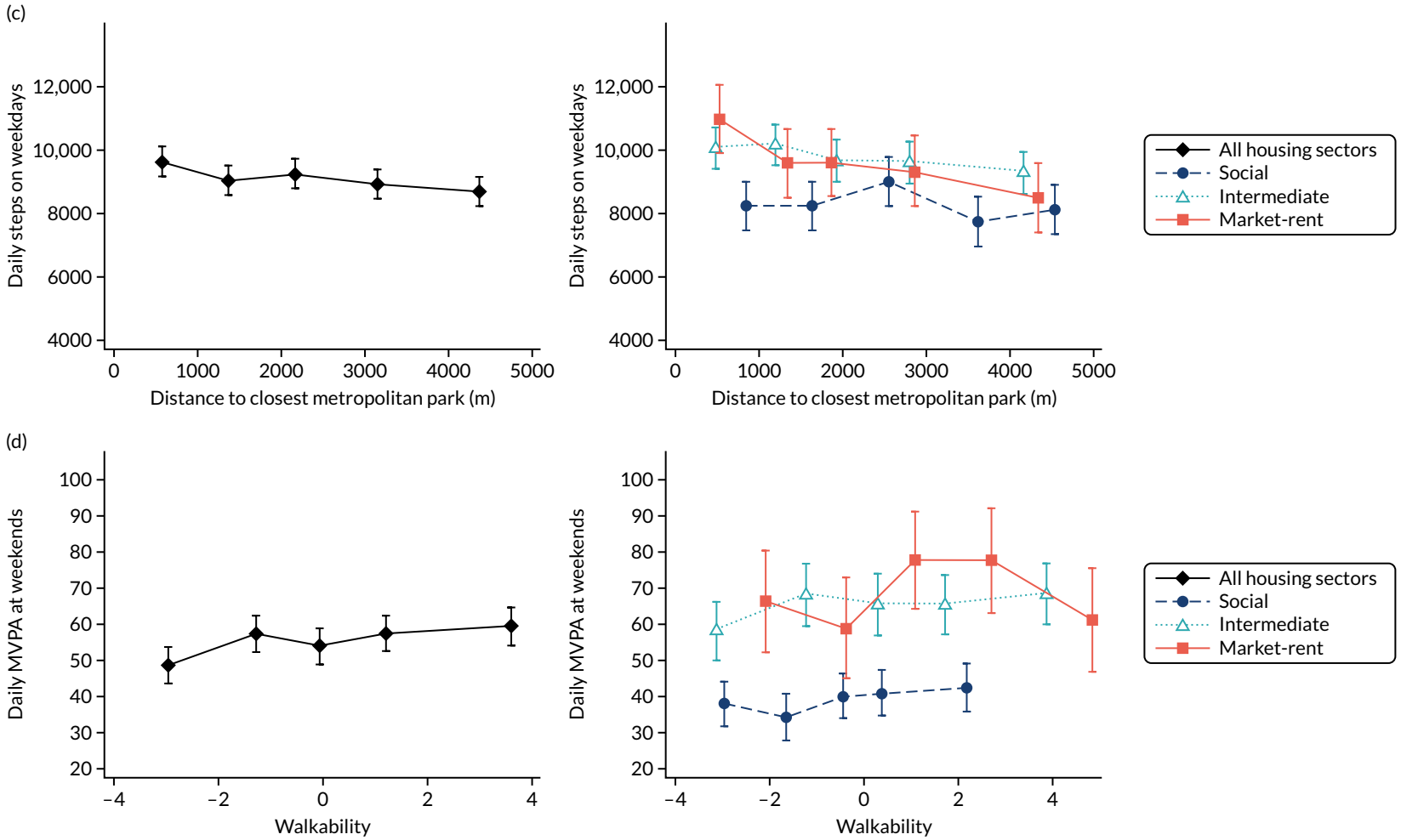

FIGURE 4 Daily steps and MVPA (mean and 95% CI) by quintile of selected residential built environmental factors, overall and by housing sector. (a) Daily steps at weekends and walkability; (b) daily steps at weekends and distance to closest local park; (c) daily steps on weekdays and distance to closest metropolitan park; (d) daily MVPA at weekends and walkability; (e) daily MVPA at weekends and distance to closest local park; and (f) daily MVPA on weekdays and distance to closest metropolitan park. Notes: mean daily steps (95% CI) at weekends or on weekdays are plotted against median value of quintile of built environment variable, for all housing sectors combined and by housing sector. Daily steps are adjusted for sex, age group, ethnic group as fixed effects and household as a random effect in a multilevel model. Daily steps for all housing sectors are additionally adjusted for housing sector as a fixed effect. Footnotes: mean daily MVPA (95% CI) at weekends or on weekdays is plotted against median value of quintile of built environment variable, for all housing sectors combined and by housing sector. Daily MVPA is adjusted for sex, age group, ethnic group as fixed effects and household as a random effect in a multilevel model. Daily MVPA for all housing sectors is additionally adjusted for housing sector as a fixed effect. (*continued*)

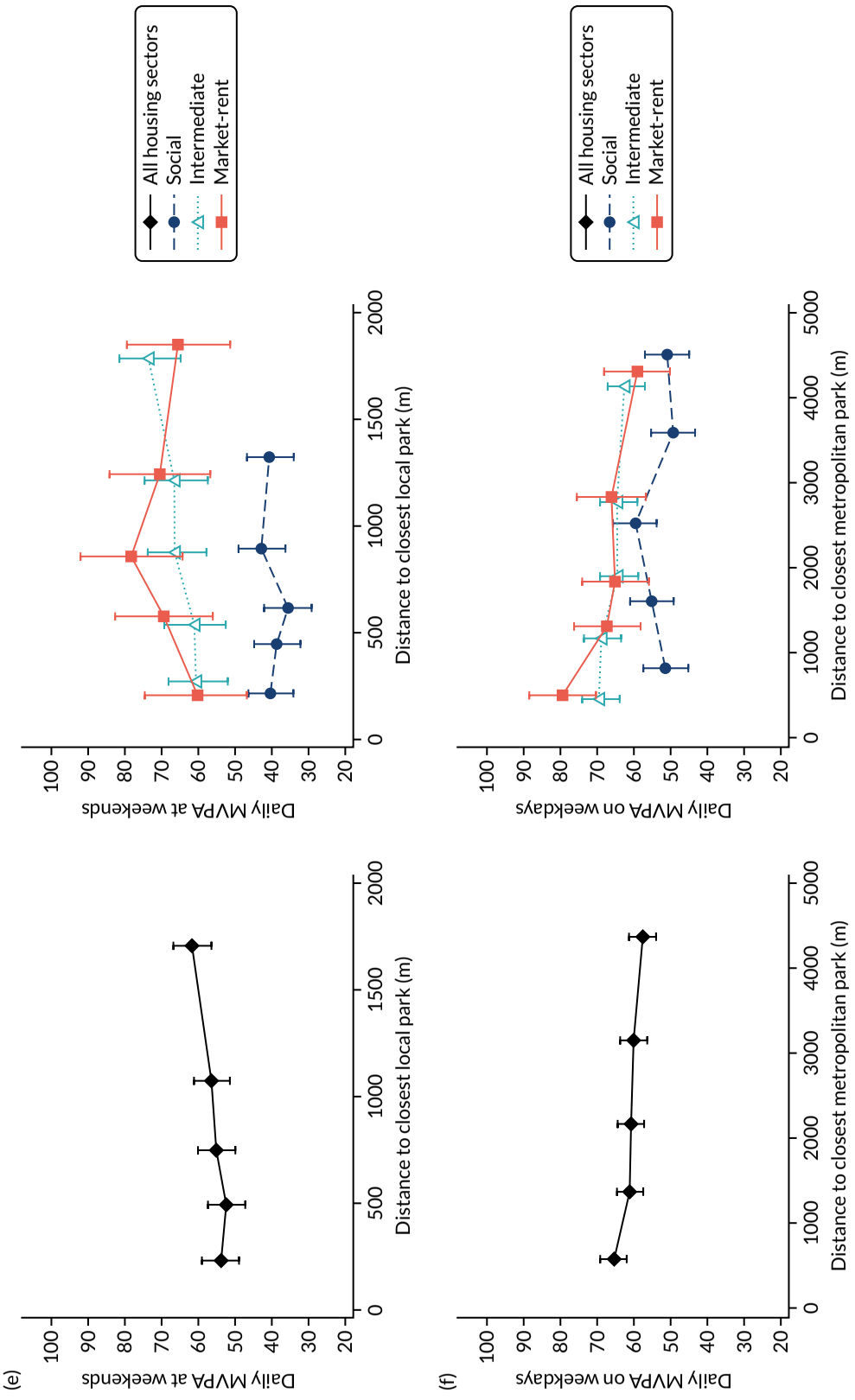

FIGURE 4 Daily steps and MVPA (mean and 95% CI) by quintile of selected residential built environmental factors, overall and by housing sector. (a) Daily steps at weekends and walkability; (b) daily steps at weekends and distance to closest local park; (c) daily steps on weekdays and distance to closest metropolitan park; (d) daily MVPA at weekends and walkability; (e) daily MVPA at weekends and distance to closest local park; and (f) daily MVPA on weekdays and distance to closest metropolitan park. Notes: mean daily steps (95% CI) at weekends or on weekdays are plotted against median value of quintile of built environment variable, for all housing sectors combined and by housing sector. Daily steps are adjusted for sex, age group, ethnic group as fixed effects and household as a random effect in a multilevel model. Daily steps for all housing sectors are additionally adjusted for housing sector as a fixed effect. Footnotes: mean daily MVPA (95% CI) at weekends or on weekdays is plotted against median value of quintile of built environment variable, for all housing sectors combined and by housing sector. Daily MVPA is adjusted for sex, age group, ethnic group as fixed effects and household as a random effect in a multilevel model. Daily MVPA for all housing sectors is additionally adjusted for housing sector as a fixed effect.

On weekend days

In minimally adjusted models, both daily steps and MVPA accumulated were positively associated with residential walkability (mean difference in daily steps and daily minutes of MVPA per unit of walkability: 255 steps, 95% CI 139 to 371 steps, and 2.2 minutes, 95% CI 1.2 to 3.1 minutes, respectively), and with the distance from home to the closest local park (mean difference in daily steps and daily minutes of MVPA per kilometre of distance to the closest local park: 1147 steps, 95% CI 669 to 1624 steps, and 9.0 minutes, 95% CI 5.2 to 12.9 minutes, respectively). Conversely, steps taken and minutes of MVPA were negatively associated with the distance (km) to the nearest metropolitan park (−363 steps, 95% CI −582 to −144 steps, and −2.9 minutes, 95% CI −4.7 to −1.2 minutes, respectively), the distance (km) to the closest district park (−370 steps, 95% CI −617 to −124 steps, and −2.9 minutes, 95% CI −4.7 to −1.2 minutes, respectively) and accessibility to public transport (−1352 steps, 95% CI −2516, to −187 steps, and −9.5 minutes, 95% CI −18.9 to −0.7 minutes, respectively, for those with low compared with those with high accessibility). After adjustment for sociodemographic characteristics, associations of residential walkability with daily steps taken (135 steps, 95% CI 28 to 242 steps) and with minutes of MVPA (1.2 minutes, 95% CI 0.3 to 2.1 minutes), and of distance from home to the nearest local park with daily steps taken (597 steps, 95% CI 161 to 1032 steps) and with minutes of MVPA (4.7 minutes, 95% CI 1.2 to 8.2 minutes) remained statistically significant. This suggests that the more walkable the residential environment the higher the number of steps taken and the greater the time spent in MVPA, and that overall the further the closest local park, the higher the number of steps taken and the greater the time spent in MVPA on weekend days (*Figure 4*); this appeared more evident in the social and intermediate housing sectors (*Figure 4*). Associations remained consistent after further adjustment for the other residential built environmental factors (model 3).

Interaction analyses

An interaction between low accessibility to public transport and social versus intermediate housing seekers in relation to mean daily steps on weekdays was observed ($p = 0.042$). However, a Wald test for the interaction term between accessibility to public transport and housing suggested that the interaction term could be omitted from the model ($p = 0.06$).

Effect of adjustment for built environmental factors and sensitivity analyses

The effect of adjustment for built environment factors on the differences between aspirational housing tenures in both daily steps and daily minutes of MVPA is presented in *Table 11*. Adjustment for walkability decreased differences in daily steps and MVPA on weekend days between social and intermediate housing seekers by 1.5% and 2.6%, respectively (i.e. a decrease of 36 steps and a decrease of 0.4 minutes in the gap between social and intermediate housing seekers). Adjustment for distance to the closest local park decreased differences in daily steps and MVPA on weekend days between social and intermediate housing seekers by 4.7% and 5.9%, respectively (i.e. a decrease of 113 steps and a decrease of 0.9 minutes). Adjustment for distance to the nearest metropolitan park reduced differences in steps taken on weekdays between social and intermediate housing seekers by 9.9% and 11.9%, respectively (i.e. a decrease of 81 steps and a decrease of 0.7 minutes). Sensitivity analyses on the subsample of 837 participants with physical activity data on both weekdays and weekends showed consistency with the main findings presented in the weekday and weekend day sensitivity analyses in the previous sections (see *Report Supplementary Materials 17–19*). The base model adjusts for sex, age group, ethnic group as fixed effects and household as a random effect to allow for clustering at the household level.

Change in built environment and change in physical activity

Descriptive analyses

Baseline descriptive statistics for the followed-up participants are shown in *Table 12*. Women, those who were middle-aged (35–49 years) and those belonging to ethnic minorities were more prevalent among social than among intermediate housing seekers ($p < 0.0001$). Compared with participants seeking intermediate accommodation, participants seeking social housing took fewer daily steps and accumulated fewer daily minutes in MVPA overall ($p < 0.0001$), on weekdays ($p < 0.01$) and on

TABLE 11 Mean differences in daily steps and MVPA for social and market-rent housing seekers compared with intermediate housing seekers: effect of adjustment for residential built environment factors

Outcome	Base model, difference (95% CI)	Base model with further adjustments, difference (95% CI)								Land use mix, difference (95% CI)
		Walkability	Distance to local parks	Distance to district parks	Distance to metropolitan parks	Accessibility to public transport	Walkability, distance to local, district and metropolitan parks, accessibility to public transport	Street connectivity	Residential density	
Weekday daily steps (N = 1053) (steps)										
Social	−898 (−1448 to −348)	−899 (−1451 to −348)	−914 (−1468 to −360)	−899 (−1452 to −347)	−817 (−1369 to −266)	−884 (−1438 to −330)	−814 (−1373 to −255)	−901 (−1452 to −350)	−888 (−1443 to −333)	−906 (−1458 to −354)
Intermediate	–	–	–	–	–	–	–	–	–	–
Market-rent	−107 (−701 to 487)	−103 (−701 to 495)	−107 (−701 to 488)	−107 (−702 to 487)	−95 (−687 to 498)	−86 (−680 to 508)	−87 (−682 to 508)	−95 (−692 to 502)	−115 (−713 to 482)	−88 (−687 to 510)
Weekday daily MVPA (N =1053) (minutes)										
Social	−6.6 (−10.9 to −2.3)	−6.6 (−10.9 to −2.3)	−6.6 (−11.0 to −2.3)	−6.7 (−11.0 to −2.4)	−5.9 (−10.2 to −1.6)	−6.4 (−10.7 to −2.1)	−5.8 (−10.2 to −1.4)	−6.6 (−10.9 to −2.3)	−6.5 (−10.8 to −2.2)	−6.5 (−10.8 to −2.2)
Intermediate	–	–	–	–	–	–	–	–	–	–
Market-rent	2.3 (−2.4 to 6.9)	2.2 (−2.4 to 6.9)	2.3 (−2.4 to 6.9)	2.3 (−2.4 to 6.9)	2.4 (−2.2 to 7.0)	2.4 (−2.2 to 7.1)	2.3 (−2.3 to 7.0)	2.4 (−2.3 to 7.0)	2.2 (−2.5 to 6.9)	2.2 (−2.5 to 6.9)
Weekend daily steps (N = 848) (steps)										
Social	−2477 (−3232 to −1721)	−2441 (−3194 to −1689)	−2364 (−3122 to −1607)	−2427 (−3184 to −1671)	−2436 (−3194 to −1678)	−2409 (−3172 to −1646)	−2242 (−3007 to −1477)	−2469 (−3224 to −1714)	−2385 (−3142 to −1627)	−2442 (−3197 to −1688)
Intermediate	–	–	–	–	–	–	–	–	–	–
Market-rent	155 (−624 to 934)	33 (−748 to 815)	149 (−628 to 925)	168 (−609 to 946)	161 (−617 to 940)	136 (−644 to 916)	38 (−742 to 818)	101 (−682 to 883)	66 (−715 to 847)	39 (−747 to 824)
Weekend daily MVPA (N = 848) (minutes)										
Social	−15.3 (−21.4 to −9.1)	−14.9 (−21.0 to −8.8)	−14.4 (−20.5 to −8.3)	−15.0 (−21.1 to −8.9)	−14.9 (−21.0 to −8.8)	−14.8 (−20.9 to −8.6)	−13.6 (−19.8 to −7.4)	−15.2 (−21.3 to −9.1)	−14.4 (−20.5 to −8.3)	−14.9 (−0.9 to −8.8)
Intermediate	–	–	–	–	–	–	–	–	–	–
Market-rent	3.3 (−3.0 to 9.6)	2.2 (−4.1 to 8.5)	3.3 (−3.0 to 9.6)	3.4 (−2.9 to 9.7)	3.4 (−2.9 to 9.7)	3.2 (−3.1 to 9.5)	2.2 (−4.1 to 8.5)	2.9 (−3.4 to 9.2)	2.6 (−3.7 to 8.9)	2.1 (−4.2 to 8.4)

Note
Base model adjusts for sex, age group and ethnic group as fixed effects and household as a random effect, to allow for clustering at household level.

TABLE 12 Baseline characteristics of the followed-up ENABLE London participants, overall and by housing sector ($n = 687$)

Characteristic	All housing sectors	Housing sector			*p*-value[a]
		Social	Intermediate	Market-rent	
Total participants, *n* (%)	687 (100)	283 (41)	301 (44)	103 (15)	
Sociodemographics*, n *(%)					
Sex: female	401 (58)	206 (73)	151 (50)	45 (44)	< 0.001
Age group (years)					
16–24	130 (19)	53 (19)	50 (17)	27 (26)	< 0.001
25–34	289 (42)	72 (26)	172 (57)	45 (44)	
35–49	223 (33)	137 (48)	70 (23)	16 (16)	
≥ 50	45 (7)	21 (7)	9 (3)	15 (15)	
Ethnicity					
White	334 (49)	52 (18)	209 (69)	73 (71)	< 0.001
Black	172 (25)	135 (48)	30 (10)	7 (7)	
Asian	110 (16)	59 (21)	43 (14)	8 (8)	
Mixed/other	71 (10)	37 (13)	19 (6)	15 (15)	
Physical activity facilities in the residential area					
Walkability, mean (95% CI)	0.0 (–0.2 to 0.2)	–0.4 (–0.6 to –0.1)	0.2 (–0.1 to 0.5)	0.4 (–0.2 to 1.1)	0.004
Street connectivity, mean (95% CI)	8.6 (8.6 to 8.7)	8.5 (8.4 to 8.7)	8.7 (8.6 to 8.9)	8.8 (8.5 to 9.1)	0.06
Residential density (1000 habitants/km^2), mean (95% CI)	11.9 (11.5 to 12.3)	10.3 (9.8 to 10.8)	12.7 (12.0 to 13.4)	13.7 (12.4 to 15.1)	< 0.001
Land use mix, mean (95% CI)	0.37 (0.36 to 0.39)	0.35 (0.33 to 0.37)	0.38 (0.36 to 0.40)	0.42 (0.38 to 0.46)	0.01
Distance to closest park (m), mean (95% CI)	663 (633 to 692)	609 (570 to 648)	703 (656 to 749)	694 (602 to 787)	0.06
Public transport accessibility (PTAL score), mean (95% CI)	4.6 (4.5 to 4.8)	4.3 (4.1 to 4.5)	4.8 (4.6 to 5.0)	5.0 (4.6 to 5.3)	< 0.001
Physical activity,[b] mean (95% CI)					
Daily steps, mean	8947 (8713 to 9182)	8162 (7742 to 8582)	9458 (9077 to 9840)	9611 (8984 to 10,238)	
Daily steps on weekdays	9173 (8915 to 9431)	8525 (8062 to 8987)	9581 (9162 to 10,000)	9754 (9065 to 10,443)	
Daily steps on weekend days	9173 (8915 to 9431)	8525 (8062 to 8987)	9581 (9162 to 10,000)	9754 (9065 to 10,443)	
Daily minutes of MVPA	60 (58 to 61)	54 (50 to 57)	63 (60 to 66)	67 (62 to 72)	
Daily minutes of MVPA on weekdays	61 (59 to 63)	56 (52 to 59)	64 (61 to 67)	69 (63 to 74)	
Daily minutes of MVPA on weekend days	55 (53 to 58)	45 (40 to 50)	61 (57 to 65)	64 (57 to 71)	

a Differences between housing sectors was tested using chi-squared (sex, age, ethnicity), analysis of variance (walkability, street connectivity, PTAL) and Kruskal–Wallis analysis of variance (residential density and distances to closest park).
b Physical activity outcomes were available for 684 participants on weekdays and for 577 participants on weekend days.

weekend days ($p < 0.0001$) at baseline. Sociodemographic characteristics and levels of physical activity at baseline of the intermediate and market-rent housing seekers were largely similar. At baseline, social housing seekers also resided in less walkable areas (walkability score social: −0.4, 95% CI −0.6 to −0.1; intermediate: 0.2, 95% CI −0.1 to 0.5; market-rent 0.4, 95% CI −0.2 to 1.1; $p = 0.004$), and had poorer accessibility to public transport (PTAL score social: 4.3, 95% CI 4.1 to 4.5; intermediate: 4.8, 95% CI 4.6 to 5.0; market-rent 5.0, 95% CI 4.6 to 5.3; $p < 0.001$).

Longitudinal changes in built environment exposures

Within-person changes in exposure to built environment factors over the 2-year period between baseline and follow-up are shown in *Table 13*. Followed-up participants experienced a positive change in neighbourhood walkability of 1.4 units (95% CI 1.2 to 1.6 units). Social housing seekers had the greatest improvement in neighbourhood walkability (1.7 units, 95% CI 1.4 to 2.0 units) compared with intermediate (1.3 units, 95% CI 0.9 to 1.6 units) and market-rent (1.0 units, 95% CI 0.3 to 1.7 units) housing participants. Improvement in walkability scores was mostly driven by increases in the residential density (7779 residential units per km^2, 95% CI 6910 to 8648 residential units per km^2) and land use mix (0.21 units, 95% CI 0.19 to 0.23 units). Participants experienced a mean decrease in distance to the nearest park of 270 m (95% CI 232 to 307 m), with no significant differences across housing sector. They also had a positive change of 0.7 units (95% CI 0.6 to 0.9 units) in accessibility to public transport. Social housing participants experienced the greatest amount of change (1.5 units, 95% CI 1.2 to 1.8 units) compared with intermediate (0.2 units, 95% CI 0.0 to 0.5 units) and market-rent (0.1 units, 95% CI −0.3 to 0.5 units) housing participants.

Overall, positive changes in the built environment exposures were mostly observed in those who relocated into East Village ($n = 357$). On average, they experienced a 2.4-unit (95% CI 2.1 to 2.7 units) increase in neighbourhood walkability, a 531-m (95% CI 488 to 574 m) decrease in the distance to their nearest park, and a 1.6-point (95% CI 1.3 to 1.9 points) increase in accessibility to public transport (see *Report Supplementary Material 20*). Comparatively small changes in exposures were observed for those who did not move to East Village ($n = 330$) (see *Report Supplementary Material 20*).

TABLE 13 Within-person change (baseline to follow-up) in residential built environment characteristics by aspirational housing tenure and combined ($n = 687$)

Change	All housing sectors ($N = 687$)	Housing sector			*p*-value
		Social ($N = 283$)	Intermediate ($N = 301$)	Market-rent ($N = 103$)	
Physical activity facilities in the residential area, mean (95% CI)					
Walkability (score)	1.4 (1.2 to 1.6)	1.7 (1.4 to 2.0)	1.3 (0.9 to 1.6)	1.0 (0.3 to 1.7)	0.03
Street connectivity (intersections per km of road)	−0.5 (−0.6 to −0.4)	−0.6 (−0.7 to −0.4)	−0.5 (−0.7 to −0.4)	−0.4 (−0.7 to −0.1)	0.63
Residential density (1000 habitants/km^2)	7.8 (6.9 to 8.7)	8.9 (7.6 to 10.2)	7.2 (5.9 to 8.5)	6.5 (4.0 to 8.9)	0.09
Land use mix (score)	0.21 (0.19 to 0.23)	0.25 (0.21 to 0.27)	0.20 (0.17 to 0.23)	0.12 (0.07 to 0.17)	< 0.001
Distance to the closest park (m)	−270 (−307 to −232)	−303 (−349 to −256)	−262 (−322 to −203)	−201 (−325 to −76)	0.19
Accessibility to public transport (PTAL score)	0.7 (0.6 to 0.9)	1.5 (1.2 to 1.8)	0.2 (0.0 to 0.5)	0.1 (−0.3 to 0.5)	< 0.001

Longitudinal associations between changes in exposure and changes in physical activity

Associations between changes in the built environment factors and changes in total daily steps and total daily MVPA (overall, weekdays and weekend days) are presented in *Table 14*. In fully adjusted models, a 1 SD increase in neighbourhood walkability was associated with an overall increase of 302 steps per day (95% CI 110 to 494 steps per day) and 360 steps per weekday (95% CI 149 to 567 steps per weekday). For residential density, a 1 SD increase was associated with an overall increase of 313 steps per day (95% CI 123 to 504 steps per day) and 452 steps per weekday (95% CI 246 to 658 steps per weekday). For land use mix, a 1 SD increase was associated with an overall increase of 201 steps per day (95% CI 5 to 398 steps per day) and 257 steps per weekday (95% CI 43 to 471 steps per weekday). Associations with physical activity on weekend days were all in the same direction as weekdays, but none reached statistical significance.

Interactions

Interactions between accessibility to public transport and housing sector in relation to mean daily steps, mean daily steps on weekdays and mean MVPA on weekdays were observed (results not shown). Effect sizes by housing sector for these associations are shown in the footnotes of *Table 14*. A 1 SD increase in accessibility to public transport was significantly associated with 395 fewer daily steps (95% CI 70 to 720 daily steps) and 2.9 fewer minutes of MVPA (95% CI 0.3 to 5.5 minutes) on weekdays for social housing seekers, but, conversely, 657 more daily steps (95% CI 4 to 1309 steps) and 5.7 more minutes of MVPA (95% CI 0.4 to 10.9 minutes) on weekdays for market-rent housing participants.

Discussion

It has been suggested that, the more walkable an urban environment is, the more attractive it is for active modes of travel such as walking.[126,127] In this study, we found that, at baseline, participants took more steps and undertook more MVPA at weekends when living in more walkable neighbourhoods. Our findings suggest that individuals may be more influenced by residential built environment factors at weekends than on weekdays, which could be explained by the greater use of their local neighbourhood during the weekend. At follow-up, there were considerable improvements in built environment exposures hypothesised to support physical activity. There were improvements in walkability driven by increases in residential density and land use mix, which were both strongly associated with physical activity. Distance to their nearest park reduced and there was an increased accessibility to public transport. These changes were mostly driven by those who moved to East Village, reflecting its location on the edge of the Queen Elizabeth II Park and the nature of the high-density neighbourhood development built on active design principles. Non-movers to East Village experienced, on average, small changes in exposure. This could be because the environment did not change in any meaningful way for those who remained at the same address, or because the residential locations that individuals moved to were similar to that at baseline. Our multivariable regression findings indicate that positive changes in neighbourhood walkability were associated with increases in daily steps and total amount of MVPA overall and on weekdays, but less so at weekends (although power to examine weekend and weekday associations was reduced).

Baseline findings

Participants took a greater number of steps at the weekend when living further away from a local park. This may arise because physical activity associated with the use of local parks relies on the journey to the park (assuming a physically active commute), rather than on the activities undertaken within them. Conversely, living further away from the closest metropolitan park was associated with fewer steps taken on weekdays. Metropolitan parks are sparser and therefore further away on average than local parks, and this may reflect decreased interest in reaching this type of park with increasing distance. Overall, our findings highlight the importance of distinguishing between different park types. This may help to explain inconsistent findings in the literature on the access to green space and physical activity, which reports both null[112,122] and positive[32,111,113,128–130] associations. Exploring individuals' mobility behaviours, for instance through the combined use of GPS and accelerometer

TABLE 14 Associations between within-person change in daily steps and daily MVPA (minutes) and increased walkability, greater distance to parks and increased accessibility to public transport in the ENABLE London study

Change in exposure (baseline to follow-up)	Overall ($n = 687$)		Weekdays ($n = 680$)		Weekends ($n = 517$)	
	Model 1[a]	Model 2[b]	Model 1[a]	Model 2[b]	Model 1[a]	Model 2[b]
Outcome: daily steps, standardised effects[c] (95% CI); p-value						
Walkability	313 (121 to 504); 0.001	302 (110 to 494); 0.002	360 (152 to 567); 0.001	358 (149 to 567); 0.001	273 (−82 to 629); 0.132	266 (−86 to 619); 0.139
Residential density	331 (141 to 521); 0.001	313 (123 to 504); 0.001	460 (255 to 666); < 0.001	452 (246 to 658); < 0.001	231 (−118 to 580); 0.194	199 (−146 to 545); 0.258
Land use mix	217 (25 to 409); 0.027	201 (5 to 398); 0.044	251 (42 to 560); 0.018	257 (43 to 471); 0.019	180 (−171 to 531); 0.315	162 (−190 to 515); 0.366
Street connectivity	135 (−59 to 324); 0.176	133 (−58 to 325); 0.173	146 (−63 to 355); 0.170	135 (−75 to 344); 0.208	104 (−249 to 458); 0.563	122 (−230 to 474); 0.497
Distance to park	33 (−159 to 224); 0.739	55 (−136 to 247); 0.571	3 (−207 to 211); 0.980	18 (−192 to 228); 0.863	26 (−327 to 380); 0.884	55 (−296 to 406); 0.760
Accessibility to public transportation	−5 (−198 to 189); 0.963	−7 (−205 to 191)[d]; 0.943	−54 (−264 to 156); 0.612	−44 (−259 to 172)[e]; 0.690	−67 (−424 to 289); 0.711	12 (−348 to 373); 0.946
Outcome: MVPA (minutes), standardised effects[c] (95% CI); p-value						
Walkability	1.8 (0.3 to 3.3); 0.018	1.7 (0.2 to 3.2); 0.026	1.7 (0.0 to 3.4); 0.047	1.6 (−0.0 to 3.3); 0.056	2.2 (−0.6 to 5.0); 0.123	2.2 (−0.6 to 5.0); 0.121
Residential density	1.8 (0.3 to 3.3); 0.017	1.7 (0.2 to 3.2); 0.031	2.3 (0.6 to 3.9); 0.008	2.1 (0.5 to 3.8); 0.012	2.2 (−0.5 to 5.0); 0.110	2.0 (−0.7 to 4.7); 0.143
Land use mix	0.9 (−0.6 to 2.4); 0.237	0.8 (−0.8 to 2.3); 0.336	0.6 (−1.1 to 2.3); 0.479	0.6 (−1.1 to 2.3); 0.498	1.7 (−1.1 to 4.4); 0.238	1.5 (−1.3 to 4.3); 0.289
Street connectivity	1.1 (−0.4 to 2.6); 0.134	1.1 (−0.4 to 2.6); 0.137	1.2 (−0.5 to 2.8); 0.170	1.0 (−0.6 to 2.7); 0.221	0.6 (−2.2 to 3.4); 0.681	0.9 (−1.9 to 3.6); 0.540
Distance to park	0.4 (−1.1 to 1.9); 0.636	0.6 (−0.9 to 2.1); 0.440	0.3 (−1.3 to 2.0); 0.687	0.5 (−1.1 to 2.2); 0.540	−0.5 (−3.3 to 2.3); 0.718	−0.2 (−3.0 to 2.6); 0.884
Accessibility to public transportation	−0.4 (−1.9 to 1.2); 0.642	−0.2 (−1.8 to 1.3); 0.755	−1.0 (−2.7 to 0.7); 0.246	−0.7 (−2.5 to 1.0)[f]; 0.400	−0.6 (−3.4 to 2.2); 0.684	0.1 (−2.7 to 2.9); 0.942

a Model 1 adjusts for clustering at household level only.
b Model 2 adjusts for sex, age group, ethnic group, aspirational housing tenure, clustering at household level and one of the environmental variables entered in turn.
c The size of the effect is for 1 SD change in the exposure.
d Effect for social group: −295 (−595 to 3), p-value = 0.053; effect for intermediate group: 172 (−122 to 466), p-value = 0.253; effect for market-rent group: 410 (−191 to 1010), p-value = 0.181.
e Effect for social group: −395 (−720 to −70), p-value = 0.017; effect for intermediate group: 124 (−194 to 443), p-value = 0.445; effect for market-rent group: 657 (4 to 1309), p-value = 0.049.
f Effect for social group: −2.9 (−5.5 to −0.3), p-value = 0.028; effect for intermediate group: −0.2 (−2.8 to 2.3), p-value = 0.872; effect for market-rent group: 5.7 (0.4 to 10.9), p-value = 0.033.

data,[131] would help unpick the use made of these different parks and refine the mechanisms by which they could be associated with weekday and weekend physical activity.

In line with other studies, we found that with poorer accessibility to pubic transport, fewer steps were taken and time spent in daily MVPA was lowest at the weekends.[32,113] This suggests that on weekends people's interest in the use of public transport may decrease with decreasing accessibility; however, there was weak evidence for an association after adjustment for sociodemographic factors. Conversely, on weekdays participants with a low accessibility to public transport were taking more daily steps than those with high accessibility. One explanation could be that participants rely on public transport for weekday activities such as commuting to work. As a result, those with poor accessibility to public transport walk more to reach transit points. Overall, differing patterning of associations on weekend days and weekdays suggest that the use of public transport depends on utility and travel function: a commute to work on weekdays and leisure and recreation at the weekends. Further exploration of the driving forces for the use of public transport on weekdays versus at weekends would be valuable to better understand the overall contribution of public transport accessibility to physical activity level.

We explored two plausible pathways through which the built environment may partly contribute to the observed aspirational housing tenure differences in physical activity: differences in the way the three groups interact with the physical activity-supportive features of their residential environment and differences in the availability of these features. We found little evidence for the former explanation, with weak evidence for an interaction. As for the latter explanation, we found that social housing seekers lived in less walkable environments, closer to local parks and further away from metropolitan parks than intermediate and market-rent housing seekers, which, in turn, were all associated with a decreased number of daily steps and daily minutes of MVPA. However, disparities in these three environmental features accounted for little of the variability in daily steps (1.5%, 4.7% and 9.9%, respectively) and in daily minutes of MVPA (2.6%, 5.9% and 11.9%, respectively) between social and intermediate participants. Our findings support previous work that suggests that housing tenure might relate to health behaviours by sorting disadvantaged people into neighbourhoods provided with fewer health-promoting amenities.[132,133]

Longitudinal findings

The longitudinal findings strengthen previous cross-sectional evidence that more walkable environments are associated with higher levels of physical activity.[110,121,134–136] The significant associations observed were mostly driven by the two components of walkability, residential density and land use mix, which were both strongly and positively associated with increased physical activity levels, consistent with other longitudinal studies.[89,95,137–140] Greater land use mix is posited to support walking by offering accessibility to a wider range of services and employment.[141] As for higher residential density, it is assumed to provide more of a critical mass of walkers seen by other people, who may, in turn, be encouraged to walk by safety in numbers[142] and/or by a desire to comply with the social norm.[143] Traffic congestion associated with higher residential density may also promote active travel.[144] Unlike others,[145,146] we did not find that a change in street connectivity was associated with a change in the number of steps taken or the amount of MVPA accumulated. This may be partly because our street connectivity metric relied on street network data and therefore fell short in capturing the permeability of newly built active design environments, like East Village, composed of large pedestrianised areas and informal footpaths. Hence, the limitation of our street connectivity measure to reflect the permeability of the residential neighbourhood as experienced by East Village movers may have underestimated the strength of the effect between walkability and physical activity.

Although the relationships between walkability (and its component variables) and physical activity on weekend days were all in the same direction, none reached statistical significance. This may be because the built environment is more likely to be associated with transportation walking than other types of physical activity, including recreational walking.[147] Alternatively, the limited number of participants

who had physical activity data available at weekends compared with weekdays may have resulted in underpowered analyses for models fitting physical activity at weekends as an outcome.

We found evidence that increasing accessibility to public transport is associated with a statistically significant decrease in physical activity on weekdays among social housing participants and, conversely, an increase in weekdays physical activity among market-rent housing participants. Among possible explanations, different patterns in the distance between home and workplace and/or in the availability of individual modes of transport across socioeconomic groups may trigger different responses to increased accessibility to public transport. Overall, socioeconomic differences in the relationship between accessibility to public transport and physical activity may explain the mixed findings outlined by some literature reviews.[147]

Unlike others, we did not find evidence that living closer to a park at follow-up than at baseline was associated with a change in physical activity level.[89] Previous studies have highlighted the importance of distinguishing between different types of park, as size and attractiveness are associated with physical activity.[128] However, since half of the ENABLE London participants were relocated to the edge of the Olympic park, a large metropolitan park with many sport facilities, such a classification became meaningless. It was difficult to disentangle the different relationship that individuals may have with different types of parks, which may partly explain the null findings.

Those who have lived in their current home for < 2 years have been found to take longer to orientate themselves within their neighbourhood and have a greater mismatch between objectively measured and perceived neighbourhood features.[148] This may partly explain the absence of findings between changes in exposure to some of the built environment features (i.e. distance to parks) and changes in physical activity behaviours. It also suggests that the associations found may strengthen over time.

Strengths

The strengths of this study include the use of validated objective measures of physical activity,[149] considering weekday/weekend variations in physical activity undertaken,[113] and exploring the contribution of the residential built environment in explaining socioeconomic differences in physical activity levels, which has been little assessed. Sensitivity analyses further strengthened the findings by showing consistent results in both the inclusive analytical sample and the more restricted sample of participants with physical activity data on both weekdays and weekends. This study is also one of very few longitudinal studies to have enabled examination of how change in GIS-derived residential built environment features is associated with change in accelerometer-based physical activity levels. Its design provided a great variability in changes of exposures to various features of the environment, facilitating the detection of associations. Moreover, a relatively large number of participants were enrolled compared with other longitudinal studies (e.g. Wells and Yang[145] and McCormack *et al.*[150]).

It is of note that these analyses looking at physical activity in relation to change in the built environment showed statistically significant increases in physical activity, whereas the increases in physical activity were not statistically significant when comparing the East Village group with those who did not move into East Village. There are a number of possible explanations that we are exploring further. In particular, 'change in walkability', for example, is a continuous measure and therefore has more power to detect changes in physical activity than using the dichotomous variable East Village or control.

Limitations

Limitations also warrant consideration. The cross-sectional study design of the baseline data does not rule out the selection of more active people into neighbourhoods supportive of physical activity, and therefore restricts interpretations about the direction of effects. Moreover, not considering physical activity facilities available in routinely visited settings other than place of residence (e.g. workplace) may have led to an overestimation of the association between the residential environment and health behaviours.[151] Because the sample was not randomly selected from the population at large, that is

the study was targeted at those seeking to move to East Village, findings may not be more broadly generalisable, which may have implications for external validity.

Conclusions

The findings indicated that the residential built environment is associated with physical activity behaviours differently at weekends and on weekdays and that changes in the residential built environment are associated with changes in physical activity, and both of these differ by weekday and weekend. There was limited evidence that socioeconomic disparities in residential built environment factors contribute to socioeconomic differences in physical activity. These findings provide strong support for considering more walkable urban designs, composed of more mixed land use and higher residential density, as levers to increase physical activity. In addition, this work also suggests that policy-makers should be sensitive to the possibility that environmental interventions might have differential impacts on physical activity at weekdays and weekends.

Chapter 5 The development of an open-source tool to identify different travel modes from hip-worn accelerometer and GPS data, and its application to the ENABLE London study

Introduction

Active travel, predominantly by walking and cycling, is an accessible form of physical activity that is associated with positive health outcomes.[152–154] Quantifying the proportion of time spent in different active travel modes is therefore important to understand how these contribute to overall physical activity and health, and to assess the effectiveness of interventions that aim to increase active travel.

Travel modes have previously been assessed using detailed travel diaries;[155] however, self-reported data have limitations, including that they may be subject to social desirability and recall bias and will often relate to only a single day of travel.[156] Activity and movement patterns are now increasingly objectively assessed using accelerometers and GPS receivers;[157–159] combining accelerometer and GPS data allows for the identification of both the intensity and the location of physical activity. This combination is potentially valuable in describing travel behaviour, and particularly active travel behaviour. In recent years, supervised machine learning has shown the potential to identify active travel from physical activity data. Supervised machine learning algorithms are trained on an example data set and are then used for prediction to other data sets. Until recently, the most promising algorithms were random forests: ensemble supervised learning algorithms where predictions are taken from a consensus across a large number of decision trees.[160–162] A related algorithm, gradient boosted trees, has recently replaced random forests as a leading algorithm for data science tasks, with many machine learning approaches using the XGBoost (University of Washington, Seattle, WA, USA) implementation of gradient boosting instead of random forests.[163,164]

Using data collected in the ENABLE London study, an algorithm was developed to distinguish five travel modes (walk, cycle, motorised vehicle, train and stationary) using accelerometer and GPS data and the supervised machine learning tool XGBoost. We then applied this algorithm to the complete baseline and follow-up ENABLE study data sets to characterise the different modes of travel throughout the day and then examined changes between baseline and follow-up in the different travel modes. All code necessary to replicate our findings and apply our predictive model to other data sets is made available as a package of the open-source statistical software environment R (The R Foundation for Statistical Computing, Vienna, Austria).[165] Full details of the methodology and a full usage example have been published.[165,166]

Development of a method to identify travel modes from accelerometry and GPS data

Methods

The method to identify travel modes from accelerometry and GPS data was developed using data collected at baseline in the ENABLE London study. Full details of this are published[166] and are summarised below. Parts of this section are adapted or reproduced from Procter *et al.*[166] This is an Open Access article distributed in accordance with the terms of the Creative Commons Attribution (CC BY 4.0) license, which permits others to distribute, remix, adapt and build upon this work, for commercial use, provided the original work is properly cited. See: http://creativecommons.org/licenses/by/4.0/. The text below includes minor additions and formatting changes to the original text.

Accelerometry has been widely used to measure physical activity, with many different devices deployed. The most common devices in the literature are the ActiGraph, Actiheart (CamNtech, Cambridge, UK), Actical (Philips Respironics, Amsterdam, the Netherlands), activPAL (PAL Technologies Ltd, Glasgow, UK) and GeneActiv (Activinsights Ltd, Huntingdon, UK), with over half of published studies up to 2015 using the ActiGraph.[167] Many of these different devices convert raw acceleration (measured in g) into a form of activity count variable, which has then been used to classify physical activity intensity and energy expenditure.[67,168–170] However, the methods used by instrument manufacturers to convert raw acceleration into counts are often unclear. For this reason, and because the raw acceleration data contain much more information to train an algorithm than derived count variables, we have made use of the raw data in this study.

Previous work on travel mode identification has been developed from the transport perspective rather than that of physical activity, where segmentation into journeys is important to assess travel behaviour.[160,171–173] A focus on journeys often results in short periods of physically active transit behaviour, such as walking between bus stops, being identified as part of a non-active travel mode. However, for physical activity researchers, quantifying the volume and intensity of physical activity when actively travelling is an essential component of the overall purpose of a journey. Consequently, it is important to identify all data points that denote active travel, so that all time in active travel modes can be quantified. As a result, we identify the travel mode of each GPS data point (recorded every 10 seconds) without prior segmentation into journeys.

Participants in the ENABLE London study were asked to wear an accelerometer (ActiGraph GT3X+) and a GPS receiver on an elasticated belt around their waist for 7 consecutive days. Participants also completed a questionnaire to describe their travel patterns to work/place of study. They reported the specific days on which they would be travelling to work or study during the ActiGraph and GPS wear period and whether or not they commuted at the same time on each day. Reported travel modes for these journeys to and from work were underground (tube), train (over ground), bus/minibus/coach, taxi, motorcycle/moped, driving a car or a van, passenger in a car or a van, bicycle, walk, jog and other. These travel modes were recategorised into walk, cycle, vehicle (taxi, motorcycle, car/van driver, car/van passenger and bus/minibus/coach) and train (underground and overground rail). Insufficient participants consistently jogged to work for us to be able to separate 'jog' as an additional mode. In addition, time of leaving and arriving for each journey to and from work were collected.

Data preparation and cleaning

The raw accelerometer data were extracted as .csv files using ActiLife 6 software (ActiGraph, Florida, USA) summarised in 10-second epochs and merged by time stamp to GPS data. For the GPS data, measures of satellite signal quality were derived using the sum of the signal to noise ratio from each satellite the GPS device was connected to at each epoch. This takes into account possible obstructions to the GPS signal caused by the participant being indoors and gives a single measure of signal quality. Variations in speed and accelerometer data across a 10-second epoch were smoothed out using a 4-minute moving window calculating mean, SD, 10th and 90th percentiles of data from each accelerometer axis and speed from the GPS device. Distance from GPS time points to train lines was calculated using a combination of Meridian 2 (Ordnance Survey, Southampton, UK) rail network data for the UK and OS OpenMAP (Ordnance Survey, Southampton, UK) data for central London.[174] Distance travelled over the previous and next minute were also calculated. All variables were chosen as they were likely to differ between travel modes: vehicles and trains have higher speed than walking and cycling; walking shows greater accelerometer activity than other modes; both vehicles and trains have metal structures that may obstruct GPS signal; distance over the previous or next minute would be low if the participant is stationary.

Development of the algorithm

A training data set was created using a subset of participants ($n = 326$) identified from the baseline data who commuted to and from work using the same mode of transport every day and specified the time that they usually travelled for both journeys. All combined accelerometer and GPS data were extracted and exported to a Geographical Information System [ArcGIS 10.4 (ESRI, CA, USA)], and all

points during the commute of each participant were manually identified to confirm the stated mode of commute. Vehicle and train journeys were confirmed by location of appropriate features (e.g. roads or rail tracks). Points in the commute clustered around a single location were classified as 'stationary'. It should be noted that 'stationary' does not imply inactive, as walking within a building will appear stationary in terms of GPS signal and be classified as such using our method. Any sequences of points for which a mode of travel could not be clearly identified were excluded, for example repeated GPS signal loss. If the participant appeared to be travelling by a method other than that stated, for example they usually commute by train but on one day they do not move along a train line, then these points were not assigned a travel mode and were excluded from the training data set.

The training data set was then used to develop a model. We tested different moving window sizes (i.e. 1-, 2-, 3-, 4-, and 5-minute moving windows) and assessed how accurate each was for predicting travel mode on a subset of the training data. To test the generalisability of our fitted model to other data sets, we compared manually identified data from 10 participants from the Sedentary Time and Metabolic Health in People with type-2 diabetes mellitus study (STAMP-2) (Professor Ashley R Cooper, University of Bristol, 2018, personal communication) data set with those predicted using our model. The STAMP-2 study was a cross-sectional observational study of sedentary behaviour in adults with newly diagnosed type 2 diabetes mellitus, conducted in two English NHS foundation trusts in south-west England. Participants in one centre wore an accelerometer and GPS monitor concurrently for 7 days, providing similar data to the ENABLE London study. The advantages of testing our model on the STAMP-2 participants are that they were independent of the ENABLE London study and recruited from a city with different travel options from that of central London. They were also recently diagnosed with type 2 diabetes mellitus, were generally older and had a higher prevalence of obesity than the ENABLE London participants. A good predictive performance on this data set would demonstrate the generalisability of our algorithm to other populations.

Results

Full results are available elsewhere;[166] a summary is provided here. Parts of this section are adapted or reproduced from Procter *et al.*[166] This is an Open Access article distributed in accordance with the terms of the Creative Commons Attribution (CC BY 4.0) license, which permits others to distribute, remix, adapt and build upon this work, for commercial use, provided the original work is properly cited. See: http://creativecommons.org/licenses/by/4.0/. The text below includes minor additions and formatting changes to the original text.

Training data

The training data set consisted of 326 participants providing 131,573 data points (365.5 hours): 66 (20%) who walked to work (12,791 points, 35.5 hours), 34 (10%) cyclists (11,607 points, 32.2 hours), 94 (29%) vehicle users (29,407 points, 81.7 hours), 132 (40%) train users (18,269 points, 50.7 hours) plus an additional 59,499 'stationary' data points (165.3 hours). Approximately one-quarter of the training data (33,529 points) were used to test moving window sizes of 1, 2, 3, 4 and 5 minutes and the 4-minute moving window resulted in the highest predictive accuracy for active travel modes. The remaining 98,387 points were used to build a cross-validated model.

Model prediction

In the model cross-validation, we correctly predicted 97.3% of points and all five travel modes were predicted with high accuracy. In comparison with manually identified data ($n = 21$), overall accuracy was still high, with 96% of predictions correct, although this was driven by the fact that most people spent most of their time stationary (83.7% of time stationary). Cycling was least well predicted. When our model was tested on the STAMP-2 data set, we correctly predicted 96.5% of points compared with manual identification of travel modes, demonstrating that our predictions performed well considering the different participants and context. However, this was again driven by our high accuracy on stationary points, which was the dominant mode (86.8% of time stationary), and the poorest-performing predictive mode was, again, cycling.

Applying the algorithm to the ENABLE London study: baseline and 2-year follow-up findings

Methods

The algorithm developed on a subset of the ENABLE London baseline data set was applied to the full baseline and 2-year follow-up accelerometry and GPS data.

Outcomes

The primary outcome was minutes of 'active' travel, that is, daily minutes of walking and cycling. Secondary outcomes were vehicle, train, stationary and total minutes.

Statistical methods

The data collection and processing procedures were identical at baseline and at follow-up. Daily GPS data were processed to classify each 10-second epoch into one of five travel modes: walking, cycling, vehicle, train and stationary. Owing to the loss of GPS signal when travelling underground by tube, thus leading to gaps in the data, further work was carried out to classify some of these gaps as 'underground', when all of the following conditions were true:

- GPS signal was lost within 200 m of an underground station or had the predicted travel mode 'train'.
- GPS signal was regained within 200 m of an underground station or had the predicted travel mode 'train'.
- The time gap between loss and reacquisition of the signal was between 2 minutes and 2 hours.
- The loss and regaining of GPS signal did not take place within 200 m of the same underground station.

It should be noted that underground trains in the London transport system also run above ground, so there is potential for overlap between 'underground' and 'train' as methods of travel in our data.

The daily 10-second epoch data were summed to provide daily minutes for each travel mode and total daily GPS minutes. Walking and cycling minutes were also combined to provide a measure of 'active travel'. This provided a data set of up to 7 days of data for each participant, with daily time spent in each travel mode. Daily data were processed to provide an average summary daily figure for each participant, using identical methods to those for the ENABLE London accelerometer data, as described in *Chapter 3*. Participants were asked to wear the accelerometer at the same time as the GPS monitor, and in line with accelerometry analyses, days where accelerometer wear time was less than 540 minutes (9 hours) were dropped from further analyses. For each mode of travel, average daily minutes at baseline were derived using multilevel linear regression models (level 1 was day within individual and level 2 was individual), regressing daily time on day order of wear, day of week and month of wear. This was repeated for the follow-up data. The change in average daily minutes from baseline to follow-up for each travel mode was then examined using multilevel linear regression models, where level 1 was individual and level 2 was household. For each travel mode, average daily minutes at follow-up was regressed on average daily minutes at baseline, East Village/control group, sex, age group and ethnic group as fixed effects and household as a random effect. The model coefficient for East Village/control group is thus the additional change in the East Village group adjusted for any change in the control group. This method of analysis measures change while controlling for regression to the mean, and has been shown to both minimise bias and maintain power. Checks were carried out to confirm that the distribution of residuals from the models were normally distributed. Sensitivity analyses included limiting to those who were working or studying at baseline. Imputation analyses for the main outcome of interest, 'active travel' (walking and cycling minutes), were carried out using multiple imputation methods using Stata Special Edition version 15 for Windows.

Results

The ENABLE London baseline cohort

At baseline, 1063 out of 1278 (83%) participants provided GPS data, of whom 991 provided ≥ 1 corresponding day with ≥ 540 minutes accelerometer wear time. Baseline characteristics for these 991 participants are shown in *Table 15*, overall and by housing sector. Across all the housing sectors,

TABLE 15 Baseline characteristics of 991 participants with GPS data at baseline

Characteristic	All housing sectors (*N* = 991)	Housing sector			*p*-value[a]
		Social (*N* = 351; 35%)	Intermediate (*N* = 446; 45%)	Market-rent (*N* = 194; 20%)	
Age (years)*, n *(%)					
16–24	209 (21)	68 (19)	82 (18)	59 (30)	< 0.001
25–34	441 (45)	91 (26)	253 (57)	97 (50)	
35–49	275 (28)	162 (46)	93 (21)	20 (10)	
≥ 50	66 (7)	30 (9)	18 (4)	18 (9)	
Sex*, n *(%)					
Female	559 (56)	260 (74)	211 (47)	88 (45)	< 0.001
Ethnic group*, n *(%)					
White	516 (52)	70 (20)	312 (70)	134 (69)	< 0.001
Black	232 (23)	174 (50)	44 (10)	14 (7)	
Asian	151 (15)	69 (20)	60 (13)	22 (11)	
Other	92 (9)	38 (11)	30 (7)	24 (12)	
NS-SEC*, n *(%)					
Higher managerial/professional	498 (51)	47 (14)	318 (72)	133 (69)	< 0.001
Intermediate occupations	154 (16)	49 (14)	70 (16)	35 (18)	
Routine/manual occupations	120 (12)	87 (25)	25 (6)	8 (4)	
Economically inactive	211 (21)	163 (47)	30 (7)	18 (9)	
Car or van in household	357 (46)	132 (50)	159 (44)	66 (41)	0.14
Working or studying	839 (85)	232 (66)	423 (95)	184 (95)	< 0.001
Work or study away from home	773 (92)	213 (92)	397 (94)	163 (89)	0.08
Mode of travel between home and work (modes not mutually exclusive)*, n *(%)					
Public transport	590 (73)	155 (69)	312 (76)	123 (69)	0.09
Private car/motorbike/taxi	113 (14)	49 (22)	48 (12)	16 (9)	< 0.001
Walk/cycle/jog	439 (54)	95 (42)	246 (60)	98 (55)	< 0.001
GPS variables (minutes), mean (SD)					***p*-value[b]**
Walking	38 (25)	32 (26)	41 (22)	43 (28)	< 0.001
Cycling	5 (10)	3 (6)	6 (11)	6 (14)	< 0.001
Walking and cycling	43 (28)	35 (27)	47 (25)	49 (31)	< 0.001
Vehicle	37 (38)	46 (47)	32 (29)	30 (33)	< 0.001
Train	14 (20)	8 (13)	18 (22)	15 (24)	< 0.001
Underground	15 (18)	8 (15)	19 (18)	17 (17)	< 0.001
Stationary	446 (194)	500 (179)	422 (192)	403 (205)	< 0.001
Total GPS minutes	554 (206)	597 (185)	538 (206)	515 (228)	< 0.001

a Chi-squared tests were used to assess differences between categories.
b Analysis of variance was used to assess differences in time spent in different travel modes between housing tenures.

two-thirds were aged < 35 years, 56% were female and 52% were of white ethnic origin. Participants from the social housing sector were more likely to be female (74%), older and of black or Asian ethnic origin. Intermediate and market-rent participants were younger, equally likely to be male or female and more likely to be of white ethnic origin. These patterns are similar to those seen in the full ENABLE London cohort (see *Chapter 2*). Overall, the majority of the cohort (85%) were either working or studying at baseline, although this fell to two-thirds in the social housing sector and was higher (95%) in the intermediate and market-rent sectors. This is reflected in the proportions that were classified as economically inactive: 47% in the social sector and 7–9% in the intermediate and market-rent sectors. Three-quarters of the cohort used public transport to travel to or from their work or study and 50% reported some walking, cycling or jogging, which can be classified as 'active travel'. The proportions of 'active travel' varied between the housing sectors: the social sector participants were less likely to walk, cycle or jog and more likely to use private transport. *Table 15* also shows the time spent in different travel modes at baseline from the GPS monitors. Participants in the intermediate and market-rent sectors were broadly similar in their average daily time spent in each travel mode. In contrast, social sector participants recorded fewer walking, train and underground minutes, and higher vehicle and stationary minutes. Differences between housing sectors for time spent in different travel modes were statistically significant for all travel modes.

Changes in mode of travel baseline to follow-up

At follow-up, 714 out of 877 (81%) participants provided GPS data, 681 with ≥ 1 corresponding day with ≥ 540 minutes of accelerometry wear time. Longitudinal analyses were restricted to 578 participants who had valid GPS data at both baseline and follow-up.

Baseline characteristics for the 578 adults with GPS data at baseline and follow-up are shown in *Table 16* by East Village/control group and housing sector. Reassuringly, age, sex, ethnicity and NS-SEC patterns were similar to those for the full 877 who were followed up (see *Chapter 2*). In the social housing sector, the East Village and control group were similar in age, sex and socioeconomic distributions, but the East Village group were more likely to be of black ethnic origin. In the intermediate sector, the East Village group were more likely to be younger, male, of white ethnic origin and economically active. In the market-rent sector, age, sex, ethnic group and socioeconomic status were similar in the East Village and control groups. There were no differences between the East Village group and the control group in the proportions of households who owned a car at baseline. Slightly fewer of the East Village group were working at baseline and 24% were classified as economically inactive compared with 18% of the control group. At baseline, there was greater use of public transport for travel to work or study among those who moved into East Village ($p = 0.004$ for all housing sectors). Use of private transport and walk/cycle/jog were similar in the East Village and control groups, although social housing sector participants were more likely to use private transport and less likely to walk/cycle/jog than intermediate and market-rent participants.

Table 17 shows the change in the neighbourhood perceptions and built environment variables for the East Village and control groups. Compared with the baseline data, those participants who had moved to East Village lived closer to their nearest park, had better access to public transport and lived in a more walkable area. They also reported more positive perceptions of their local area. These differences were most marked for social housing sector participants.

The effect of moving to East Village on the time spent in different travel modes is shown in *Table 18*. Overall, there was little change in participants' walking or cycling minutes. However, vehicle minutes decreased overall by 7–8 minutes per day, with greater effects in the intermediate housing sector (10 minutes' decrease, 95% CI −17 to −2 minutes' decrease; $p = 0.01$), and time spent travelling by underground increased by 3–4 minutes, particularly in the market-rent sector (12 minutes, 95% CI 4 to 19 minutes; $p = 0.001$). There were large decreases in both stationary and total minutes; however, this was as a result of issues with the GPS signal being blocked by East Village housing, discovered after follow-up had been completed.

TABLE 16 Baseline characteristics of those with GPS data at baseline and follow-up

Characteristic	All housing sectors (*N* = 578)			Housing sector					
				Social (*N* = 201)		Intermediate (*N* = 283)		Market-rent (*N* = 94)	
	Control (*n* = 285; 49%)	East Village (*n* = 293; 51%)	*p*-value	Control (*n* = 74; 37%)	East Village (*n* = 127; 63%)	Control (*n* = 141; 50%)	East Village (*n* = 142; 50%)	Control (*n* = 70; 74%)	East Village (*n* = 24; 26%)
Age (years)*, n *(%)									
16–24	44 (15)	68 (23)	0.005	7 (9)	26 (20)	20 (14)	29 (20)	17 (24)	13 (54)
25–34	116 (41)	133 (45)		18 (24)	34 (27)	65 (46)	93 (65)	33 (47)	6 (25)
35–49	100 (35)	80 (27)		44 (59)	57 (45)	46 (33)	19 (13)	10 (14)	4 (17)
≥ 50	25 (9)	12 (4)		5 (7)	10 (8)	10 (7)	1 (1)	10 (14)	1 (4)
Sex*, n *(%)									
Female	173 (61)	159 (54)	0.12	58 (78)	91 (72)	82 (58)	57 (40)	33 (47)	11 (46)
Ethnic group*, n *(%)									
White	152 (53)	161 (55)	0.001	17 (23)	24 (19)	87 (62)	117 (82)	48 (69)	20 (83)
Black	48 (17)	78 (27)		22 (30)	75 (59)	21 (15)	3 (2)	5 (7)	0 (0)
Asian	57 (20)	30 (10)		29 (39)	13 (10)	23 (16)	15 (11)	5 (7)	2 (8)
Other	28 (10)	24 (8)		6 (8)	15 (12)	10 (7)	7 (5)	12 (17)	2 (8)
NS-SEC*, n *(%)									
Higher managerial/professional	163 (57)	130 (45)	0.03	17 (23)	16 (13)	97 (69)	99 (70)	163 (70)	15 (63)
Intermediate occupations	43 (15)	56 (19)		12 (16)	21 (17)	18 (13)	29 (21)	13 (19)	6 (25)
Routine/manual occupations	29 (10)	33 (11)		16 (22)	24 (19)	11 (8)	9 (6)	2 (3)	0 (0)
Economically inactive	50 (18)	71 (24)		29 (39)	64 (51)	15 (11)	4 (3)	6 (9)	3 (13)
Car or van in household	111 (46)	104 (46)	0.96	31 (53)	47 (51)	55 (46)	49 (43)	25 (41)	8 (40)
Working or studying	245 (86)	240 (82)		51 (69)	80 (63)	128 (91)	138 (97)	66 (94)	22 (92)
Work or study away from home	217 (89)	226 (94)	0.04	44 (86)	74 (92)	118 (92)	132 (96)	55 (83)	20 (89)

continued

TABLE 16 Baseline characteristics of those with GPS data at baseline and follow-up (*continued*)

Characteristic	All housing sectors (*N* = 578)			Housing sector					
				Social (*N* = 201)		Intermediate (*N* = 283)		Market-rent (*N* = 94)	
	Control (*n* = 285; 49%)	East Village (*n* = 293; 51%)	*p*-value	Control (*n* = 74; 37%)	East Village (*n* = 127; 63%)	Control (*n* = 141; 50%)	East Village (*n* = 142; 50%)	Control (*n* = 70; 74%)	East Village (*n* = 24; 26%)
Mode of travel to or from work or study (not mutually exclusive)*, n *(%)									
Public transport	156 (67)	182 (79)	0.004	31 (66)	56 (74)	83 (67)	110 (82)	42 (67)	16 (76)
Private car/motorbike/taxi	35 (15)	28 (12)	0.36	10 (21)	16 (21)	19 (15)	10 (7)	6 (10)	2 (10)
Walk/cycle/jog	141 (61)	128 (55)	0.27	19 (40)	40 (53)	82 (67)	77 (57)	40 (63)	11 (52)
GPS variables (minutes), mean (SD)									
Walking	40 (26)	38 (24)	0.003	31 (21)	31 (25)	41 (24)	43 (22)	47 (31)	38 (28)
Cycle	6 (13)	4 (7)	0.06	2 (3)	2 (4)	7 (14)	5 (9)	8 (18)	2 (4)
Walking and cycling	46 (30)	41 (26)	0.84	33 (22)	34 (26)	48 (28)	48 (25)	55 (36)	40 (28)
Vehicle	37 (38)	38 (39)	0.98	43 (47)	49 (48)	36 (32)	29 (28)	34 (38)	32 (30)
Train	15 (21)	15 (19)	0.55	8 (12)	9 (14)	16 (23)	20 (22)	17 (25)	12 (12)
Underground	14 (17)	15 (18)	0.58	12 (20)	8 (15)	15 (17)	21 (18)	16 (16)	19 (15)
Stationary	440 (193)	449 (188)	0.73	507 (192)	496 (184)	421 (190)	418 (179)	407 (184)	380 (207)
Total GPS	552 (207)	558 (195)	0.02	602 (201)	596 (190)	537 (206)	537 (188)	529 (210)	482 (225)

TABLE 17 Change in measures of the built environment and neighbourhood perceptions from baseline to follow-up

Measure	All housing sectors, mean (95% CI); *p*-value	Housing sector, mean (95% CI); *p*-value		
		Social	Intermediate	Market-rent
Built environment characteristics				
Control group				
Total participants (*n*)	256	73	127	56
Distance to closest park (m)[a]	28 (−23 to 78); 0.28	27 (−44 to 97); 0.45	31 (−39 to 101); 0.39	21 (−123 to 166); 0.77
Access to public transport (PTAL)[b]	−0.1 (−0.3 to 0.1); 0.35	−0.2 (−0.5 to 0.1); 0.20	−0.1 (−0.4 to 0.3); 0.63	0.0 (−0.5 to 0.4); 0.94
Walkability[c]	0.3 (0.0 to 0.6); 0.09	−0.2 (−0.7 to 0.3); 0.38	0.5 (0.0 to 1.0); 0.04	0.3 (−0.2 to 0.9); 0.25
Land use mix[d]	0.02 (0.00 to 0.04); 0.08	−0.02 (−0.05 to 0.01); 0.22	0.04 (0.01 to 0.08); 0.03	0.02 (−0.02 to 0.06); 0.25
Residential density[e]	1.8 (1.0 to 2.7); < 0.001	1.2 (0.2 to 2.3); 0.02	2.1 (0.7 to 3.5); 0.003	2.0 (0.2 to 3.8); 0.03
Street connectivity[f]	−0.1 (−0.2 to 0.1); 0.38	−0.2 (−0.4 to 0.0); 0.13	0.0 (−0.2 to 0.2); 0.93	−0.1 (−0.4 to 0.2); 0.63
East Village group				
Total participants (*n*)	277	124	130	23
Distance to closest park (m)[a]	−547 (−597 to −498); < 0.001	−463 (−529 to −397); < 0.001	−602 (−673 to −530); < 0.001	−693 (−952 to −435); < 0.001
Access to public transport (PTAL)[b]	1.2 (0.9 to 1.5); < 0.001	2.0 (1.5 to 2.5); < 0.001	0.7 (0.2 to 1.1); 0.007	0.3 (−0.9 to 1.5); 0.61
Walkability[c]	2.4 (2.1 to 2.7); < 0.001	2.7 (2.3 to 3.1); < 0.001	2.0 (1.5 to 2.5); < 0.001	2.4 (0.4 to 4.3); 0.02
Land use mix[d]	0.38 (0.36 to 0.41); < 0.001	0.40 (0.37 to 0.43); < 0.001	0.37 (0.34 to 0.41); < 0.001	0.35 (0.23 to 0.47); < 0.001
Residential density[e]	14.4 (12.8 to 16.0); < 0.001	14.7 (12.3 to 17.0); < 0.001	13.3 (11.0 to 15.6); < 0.001	19.1 (12.4 to 25.9); < 0.001
Street connectivity[f]	−1.1 (−1.2 to −0.9); < 0.001	−0.9 (−1.1 to −0.7); < 0.001	−1.2 (−1.4 to −1.0); < 0.001	−1.2 (−2.0 to −0.4); 0.006
Neighbourhood perceptions[g]				
Control group				
Total participants (*n*)	285	74	141	70
Crime score	0.6 (0.1 to 1.0); 0.02	1.3 (0.4 to 2.2); 0.005	0.0 (−0.7 to 0.7); 1.00	1.0 (0.0 to 1.9); 0.04
Quality score	0.7 (0.2 to 1.2); 0.01	1.5 (0.6 to 2.4); 0.001	0.1 (−0.6 to 0.9); 0.73	0.9 (0.0 to 1.9); 0.06

continued

TABLE 17 Change in measures of the built environment and neighbourhood perceptions from baseline to follow-up (*continued*)

Measure	All housing sectors, mean (95% CI); *p*-value	Housing sector, mean (95% CI); *p*-value		
		Social	Intermediate	Market-rent
East Village group				
Total participants (*n*)	293	127	142	24
Crime score	4.7 (4.1 to 5.2); < 0.001	6.1 (5.2 to 7.1); < 0.001	3.5 (2.8 to 4.2); < 0.001	3.8 (1.7 to 5.9); 0.001
Quality score	7.0 (6.4 to 7.5); < 0.001	7.9 (7.0 to 8.7); < 0.001	6.3 (5.5 to 7.1); < 0.001	6.5 (5.1 to 7.9); < 0.001

a Distance to closest park from choice of local, district and metropolitan parks.
b PTAL is a TfL score assessing the availability of public transport options. A high score indicates good public transport links.
c Walkability: the sum of three *z*-transformed variables, land use mix, residential density and street connectivity.
d Land use mix: the heterogeneity with which five functionally different land uses (residential, commercial, office, entertainment and institutional) are co-located in space. Values are normalised between 0 and 1, where 0 indicates single use and 1 indicates a perfectly even distribution of square footage across the different types of land use.
e Residential density: the number of residential units per km^2 of land devoted to residential use, including residential building footprint and attached gardens, expressed in 1000 residential units/km^2.
f Street connectivity: the number of intersections per km of road.
g Neighbourhood perception scores from exploratory factor analysis on 14 neighbourhood perception items in the questionnaire. A higher score indicates perception of less crime and higher quality in the neighbourhood.

TABLE 18 Change in daily minutes of activity measured by GPS in the East Village group relative to change in the control group, overall and by housing sector

Change	All housing sectors (*N* = 578), effect (95% CI); *p*-value	Housing sector, effect (95% CI); *p*-value		
		Social (*N* = 201)	Intermediate (*N* = 283)	Market-rent (*N* = 94)
Daily walking minutes				
Model 1[a]	−1.3 (−4.9 to 2.3); 0.49	−0.3 (−6.4 to 5.8); 0.92	0.1 (−5.1 to 5.3); 0.97	−4.9 (−15.5 to 5.7); 0.36
Model 2[b]	−1.7 (−5.4 to 2.0); 0.36	−1.8 (−8.4 to 4.8); 0.59	−1.9 (−7.5 to 3.8); 0.52	−4.2 (−15.4 to 7.0); 0.46
Model 3[c]	−1.4 (−5.3 to 2.5); 0.48			
Daily cycling minutes				
Model 1[a]	0.7 (−0.8 to 2.2); 0.34	0.5 (−0.5 to 1.5); 0.37	1.6 (−0.9 to 4.1); 0.21	1.9 (−3.3 to 7.0); 0.48
Model 2[b]	0.7 (−0.8 to 2.2); 0.36	0.3 (−0.8 to 1.4); 0.58	1.0 (−1.6 to 3.7); 0.44	1.9 (−3.6 to 7.4); 0.50
Model 3[c]	1.1 (−0.5 to 2.7); 0.17			
Daily walk plus cycle minutes				
Model 1[a]	−0.7 (−4.7 to 3.3); 0.75	0.1 (−6.2 to 6.4); 0.98	1.6 (−4.2 to 7.3); 0.59	−2.2 (−15.4 to 11.0); 0.74
Model 2[b]	−1.1 (−5.2 to 2.9); 0.59	−1.5 (−8.4 to 5.4); 0.68	−0.9 (−7.1 to 5.4); 0.78	−2.4 (−16.0 to 11.3); 0.74
Model 3[c]	−0.4 (−4.7 to 3.8); 0.85			

TABLE 18 Change in daily minutes of activity measured by GPS in the East Village group relative to change in the control group, overall and by housing sector (*continued*)

Change	All housing sectors (*N* = 578), effect (95% CI); *p*-value	Housing sector, effect (95% CI); *p*-value		
		Social (*N* = 201)	Intermediate (*N* = 283)	Market-rent (*N* = 94)
Vehicle minutes				
Model 1[a]	−7.6 (−13.0 to −2.2); 0.01	−7.2 (−18.9 to 4.5); 0.23	−11.4 (−18.2 to −4.7); < 0.001	−5.9 (−18.2 to 6.4); 0.35
Model 2[b]	−7.0 (−12.5 to −1.5); 0.01	−6.2 (−18.9 to 6.6); 0.34	−9.6 (−16.9 to −2.2); 0.01	−6.9 (−19.9 to 6.1); 0.30
Model 3[c]	−8.3 (−14.0 to −2.5); 0.01			
Train minutes				
Model 1[a]	−1.4 (−4.2 to 1.4); 0.32	−0.1 (−3.9 to 3.7); 0.95	−1.3 (−5.4 to 2.8); 0.53	2.1 (−7.5 to 11.7); 0.67
Model 2[b]	−1.7 (−4.6 to 1.1); 0.23	−1.7 (−5.8 to 2.4); 0.41	−1.5 (−6.0 to 3.0); 0.51	0.2 (−10.1 to 10.6); 0.97
Model 3[c]	−0.8 (−3.7 to 2.2); 0.62			
Underground minutes				
Model 1[a]	2.6 (0.0 to 5.1); 0.05	2.9 (−0.9 to 6.6); 0.14	2.2 (−1.8 to 6.2); 0.27	10.9 (4.1 to 17.6); 0.002
Model 2[b]	2.6 (0.1 to 5.2); 0.04	4.0 (−0.1 to 8.1); 0.06	1.6 (−2.7 to 6.0); 0.46	11.5 (4.4 to 18.6); 0.001
Model 3[c]	3.9 (1.2 to 6.5); 0.005			
Stationary minutes				
Model 1[a]	−248 (−278 to −218); < 0.001	−346 (−393 to −299); < 0.001	−199 (−243 to −155); < 0.001	−143 (−229 to −56); 0.001
Model 2[b]	−248 (−279 to −217); < 0.001	−354 (−405 to −304); < 0.001	−205 (−252 to −157); < 0.001	−127 (−217 to −38); 0.01
Model 3[c]	−247 (−279 to −214); < 0.001			
Total minutes				
Model 1[a]	−256 (−289 to −223); < 0.001	−347 (−400 to −295); < 0.001	−211 (−259 to −162); < 0.001	−139 (−234 to −44); 0.004
Model 2[b]	−255 (−289 to −222); < 0.001	−357 (−412 to −302); < 0.001	−217 (−269 to −164); < 0.001	−126 (−223 to −29); 0.01
Model 3[c]	−253 (−288 to −217); < 0.001			

a Model 1: adjusted for household as a random effect.
b Model 2: model 1 plus sex, age group and ethnic group as fixed effects.
c Model 3: model 2 plus housing sector as a fixed effect in the combined model.

Discussion

Using the ENABLE London study accelerometry and GPS data, we have developed an accurate predictive algorithm that identifies five travel modes, including the active travel modes walking and cycling, and identifies each travel mode correctly > 90% of the time. Our levels of accuracy in cross-validation outperform recent similar studies.[160,162] The models developed here are freely available to apply to similar data in the statistical software environment R.[165] We have applied this algorithm to the complete baseline and 2-year follow-up ENABLE London data sets to characterise the travel patterns of a large group of adults in London, identifying time spent in different modes of travel. Furthermore, we have examined changes in time spent in different travel modes following a move to East Village. Despite the built environment variables showing that East Village is a more walkable area, we found no change

in the time spent walking or cycling compared with those living elsewhere. However, there was some suggestion that vehicle travel had decreased, particularly in the intermediate housing sector, and that underground travel had increased, more so in the market-rent sector.

Strengths of the algorithm developed

Our study has a number of important strengths. Applying the algorithm to the STAMP-2 data set resulted in similar levels of accuracy of travel mode prediction within a very different group of participants living in a different environmental setting. This finding suggests that our method may be generalisable to other data sets and could be used by other researchers without the time-consuming steps of creating new training data. However, until more robust tests have been completed, we would recommend a manual identification checking stage similar to our methods to verify the generalisability of the method.

We exhibit similar levels of accuracy to the personal activity location measurement system (PALMS),[173] which is a freely available method to process physical activity data. The purpose of the output is somewhat different though, with PALMS identifying journeys and our method identifying each data point. The preferred method will depend on the research question. One advantage of our R package that the server-based system in PALMS does not have is that it can be run on a researcher's own machine. Data used for the present (and other similar) analyses are subject to strict data privacy and ethical conditions. Running the analyses on a researcher's own machine, rather than uploading to a server for remote processing, can help avoid problems related to data privacy. Furthermore, our method is open source, which means that all code is freely available online.[165] As a result, other researchers can suggest edits and improvements and contribute to the development of our method, and its utility to the research community.

The prediction of active travel modes should complement existing analyses of physical activity using accelerometers. Accelerometers have been used with great effect to objectively quantify activity, but they are not without limitations. A well-known problem of traditional physical activity analyses using accelerometers is that cycling is not recognised as a form of MVPA because cycling generates relatively low readings on a waist-worn accelerometer compared with other active modes. Identification of cycling from combined accelerometer and GPS data will allow better quantification of cycling as a form of physical activity. Traditional physical activity analyses will still miss cycling as a form of activity whereas our method will quantify it, albeit with moderate precision. Furthermore, assessment of active travel using our method will help to understand how people are active. For example, activity at a single location, such as at home or at the gym, will not be classed as active travel using our method but as a stationary travel mode; therefore, a participant may show high levels of overall physical activity but low levels of active travel. Incorporation of this extra information will help to understand participants' overall physical activity patterns. For example, if a participant shows increased physical activity but not active travel, it is likely that they have increased their activity at locations such as at home or at the gym. If we see no change in physical activity but an increase in active travel, then participants have replaced some of their physical activity at a location with active travel.

Limitations of the algorithm developed

It is unsurprising that our accuracy scores are lower when compared with manual identification of both participants within this study and from elsewhere than in cross-validation of the training data set. Identification is most likely to be accurate during journeys of a consistent mode, which is how the training data were defined. In full days of data there are likely to be other more ambiguous forms of movement that may be short in duration and, therefore, difficult to identify, or which do not fully represent one of the forms of travel we have included. Our model performs least well for the detection of cycling and, therefore, is probably overfitted to our training data. As a result, we would recommend manual checking of cycling data to improve accuracy. In this study, cycling represents a relatively small amount of total time; therefore, manual checking of this subset represents a much smaller time investment than in the full analysis.

Visual inspection of the data in the GIS revealed that much of the disagreement between prediction and manual classification was found at the start and the end of journeys. This highlights the challenge of identifying modal shift, that is when to switch from one mode to another. This is a limitation of the current method and all other indirect methods. However, the strength of identifying individual data points rather than full journeys is that the imprecision in identifying modal shift leads to small numbers of misclassified points, rather than entire misclassified journeys. Small numbers of misclassified points will only have a small effect on total time in each travel mode. Our inaccuracy at the start and end of trips means that any prediction to a data set where many short-duration trips are expected would be predicted to yield lower accuracy. Conversely, within a data set containing longer journeys, travel mode should be able to be identified with greater precision.

It is also worth highlighting that some disagreement within our test data sets may not be true errors. For example, if a participant is stationary but on a train it is questionable whether they should be classified as using a train or stationary; this may not matter as long as the rule is applied consistently. However, when comparing the predicted and manually derived methods this causes disagreement because during manual classification stationary points on train lines were termed stationary (e.g. standing at a train station), yet the algorithm identifies them as 'train'. A number of the misclassifications between our manual identification and predicted data sets may, therefore, be open to interpretation and may not be true misclassifications.

Using the model

First, we were only able to identify the active modes of walking and cycling: there is no consideration of running or any other activity. This limitation is based on our study sample, where no commuters consistently used these modes so we could not include them in our training data. However, walking and cycling represent the most frequently used active transport modes and other modes were rarely reported by our participants. Any form of running will most likely be identified as walking using our method because of the high acceleration that running causes on an accelerometer, and so will still be identified as active travel. We therefore feel that this limitation will have little impact on our study, although we would recommend caution in applying our method to a data set where a large quantity of running is expected. Second, we have demonstrated our capacity to identify major travel modes but were not able to discriminate car travel from public transport. Consequently, if a study is attempting to quantify the use of public transport then the current method is inadequate. To address this, we have developed a second model that discriminates bus travel. However, this leads to reduced overall accuracy, because the pattern of speed/activity can be confused between buses and other vehicles. Further work in this area would need to assess the generalisability of our methods. Third, although we assess different geographical contexts, both are in the UK. We do not know how well the method would perform elsewhere in the world, where other transport options may be available. Furthermore, we have only tested the current model on adults, and further research could assess how well our model performs on older adults or children, to potentially be of use in a wider group of studies.

Applying the model to the ENABLE London baseline and follow-up data

Using the algorithms developed on a subset of the baseline ENABLE London GPS and accelerometry data sets, we have been able to characterise the travel use of a large group of adults in London and identify the time spent in different modes of travel. Furthermore, we have examined changes in the time spent in different travel modes following a move to East Village. However, despite the built environment variables showing that East Village is a more walkable area, we found no change in the time spent walking or cycling compared with those living elsewhere. However, there was some suggestion that vehicle travel had decreased, particularly in the intermediate housing sector, and that underground travel had increased, more so in the market-rent sector.

Strengths of applying the model to the ENABLE London data

The East Village neighbourhood was designed to encourage active living. Restrictions are placed on parking facilities in East Village but it has good public transport links, being close to Stratford station

with both overground links and underground links. Half of the cohort were living in East Village at 2-year follow-up and half had either stayed at their baseline address or moved elsewhere. Following up the same individuals 2 years later enabled us to examine change in behaviour at an individual level with participants acting as their own controls. The GPS monitors were worn at the same time as the accelerometers, which provided direct and time-stamped comparisons of physical activity and location. GPS monitors rely on having good signal links with satellite receivers and the signals can be blocked by some buildings and when travelling underground, but the concurrent use of accelerometry data helped to identify different modes of travel and daily wear time. The eligibility criteria for moving into East Village, set externally by the housing association and companies, meant that we could examine differences between three housing sectors: social, intermediate and market-rent. Eligibility for these different housing sectors was based on income, which provided a measure of socioeconomic status. Finally, our method of analysis, regressing follow-up-values on baseline values, allows direct comparison of change in outcomes between the East Village and the control groups and minimised the issues of regression to the mean.

Limitations

Lack of adequate wear time led to a reduced sample of 548 participants with GPS data at both baseline and follow-up. However, baseline demographic characteristics were similar to the full cohort. After data collection had been completed and the GPS data were being processed, it was discovered that the East Village housing blocked the transmission of the GPS signal leading to low GPS-recorded time in the East Village group. However, as the accelerometers were worn at the same time as the GPS monitors and provided an estimate of wear time, we were able to use this as a proxy for wear time for the GPS monitor. Additionally, the decrease in total GPS minutes was almost identical to the decrease in stationary time in the East Village group, confirming that the GPS time lost was most likely to be spent stationary by participants in their East Village homes.

Conclusions

In summary, we have developed a method to identify travel modes from accelerometer, GPS and GIS data for the ENABLE London study, which successfully predicts > 90% of points tested in a range of contexts. This method can be of use to complement existing analyses of physical activity data and assess active travel alongside physical activity. All code necessary to replicate the analysis, apply the method to other data sets or predict from our models to other data sets is provided to facilitate usage by other researchers.

Chapter 6 Mental health, well-being and neighbourhood perceptions

Background

In this chapter, the effect of change in the built environment on the mental health (depression and anxiety) and well-being of the ENABLE London study cohort is examined, overall and by housing sector. This chapter also examines whether or not change in neighbourhood perceptions is associated with change in mental health and well-being.

Introduction

Depression and anxiety are recognised as global causes of disease.[176] Depressive disorders are one of the leading causes of years lived with disability and a leading cause of disability-adjusted life-years.[176] Globally, > 30 million people, 4.4% of the world population,[176] are estimated to be affected by depression. This number is increasing, especially in low-income countries where common mental disorders (CMDs) such as depression and anxiety are more likely to occur as a result of population increases and people living longer.[176,177] These figures highlight the importance of non-fatal health outcomes in the measurement of disease burden.[178] In the UK, CMDs are the most prevalent health condition.[179] Around one in six people in England report depression and/or anxiety at any one time.[180] Subjective well-being (how people feel about their lives) is recognised to be a critical measure of the overall mental health status of the population and an important marker of quality of life,[181] a key indicator of inequalities in health.[182]

There is a growing recognition of the importance of the local built environment to mental health. Increasing evidence from both cross-sectional and longitudinal studies suggests that both structural and social attributes of a neighbourhood can affect the mental health of residents.[183–185] Negative perceptions of the neighbourhood (e.g. perceived level of accessibility to green space, more crime, feeling unsafe, less walkability) have been found to be associated with depression, anxiety,[186–188] and both physiological and self-reported measures of stress.[189] Positive perceptions are associated with higher rates of physical activity, which, in turn, may reduce depression and cardiovascular risk with potential benefits for both physical and mental health.[190]

The World Health Organization reports that through healthier environments premature death and disease can be prevented, and estimates that 23% of global mortality is caused by modifiable environmental factors.[191] Environments that are healthy and sustainable (i.e. well-designed, accessible features such as walkability, transport and green space) provide residents with positive perceptions of where they live, which can lead to better mental health and enhanced well-being, and improve both physiological and self-reported measures of stress.[189] Positive perceptions are associated with higher rates of physical activity, which, in turn, may reduce depression and cardiovascular risk and, therefore, have potential benefits for both physical and mental health.[190] The influence of the built environment on mental health may be stronger among those who are more socioeconomically disadvantaged[188] and who often reside in poor-quality environments[192–194] characterised by lower perceived safety, access to fewer shops and leisure facilities, and higher levels of crime;[195,196] however, the evidence is weak.

The ENABLE London study provided a unique opportunity to evaluate the effect of moving into accommodation based on active design principles on mental health and well-being outcomes.

Methods

Outcomes

Depression, anxiety and well-being

Depression and anxiety at baseline and follow-up were measured using the Hospital Anxiety and Depression Scale; seven items assessed depression and seven items assessed anxiety.[57] Each item was scored between 0 and 3, which provided a maximum score of 21 for each subscale. Higher scores indicated the presence of depression and anxiety. One missing response on any of the subscales was imputed using the mean from the sum of scores in each subscale.[197] Three questions examined well-being: 'Overall, how satisfied are you with your life nowadays?', 'Overall, to what extent do you feel that the things you do in life are worthwhile?' and 'Overall, how happy did you feel yesterday?'. Each item was rated on a scale from 1 (not at all) to 10 (extremely), with higher scores indicating positive well-being.[198]

Neighbourhood perceptions

Two neighbourhood perception scales were developed at baseline, crime-free and quality, using exploratory factor analysis on 14 neighbourhood perception items included in the questionnaire[64] (see *Chapter 3* for further details). Scores for each participant were derived for each scale; higher scores indicated positive neighbourhood perceptions, that is that neighbourhoods were crime-free and were of better neighbourhood quality. The same items were used to derive scores at follow-up.

Statistical methods

Baseline

Univariate analyses examined baseline differences in the proportion of participants who reported depression, anxiety and low levels of well-being, and baseline differences in mean neighbourhood perception scores by housing sector and between East Village and control groups. Multilevel logistic regression models were used to examine the associations between the housing sector and the binary outcomes of depression, anxiety and well-being, which allowed for household clustering as a random effect (model A), with adjustment for covariates including age, sex and ethnicity (model B), marital status (model C), educational level (model D) and health status (i.e. 'LLI', model E). Analyses were restricted to 1213 (95%) participants with complete data on all outcomes and covariates at baseline.

Follow-up

A total of 92% ($n = 808/877$) of participants had complete data on all outcomes of interest at follow-up. Multilevel linear regression models examined change in the levels of depression, anxiety, well-being and neighbourhood perceptions, comparing those who moved to East Village with those who did not, for the cohort as a whole and in stratified analyses by housing sector. Analyses were adjusted for baseline household clustering, as well as age group, sex and ethnic group (model 1). Associations between change in mental health/well-being outcomes and change in neighbourhood perception scores were also examined.

Results

At baseline, 14% of the cohort were classified as depression cases, 31% reported anxiety and one-quarter reported lower levels of well-being (see *Table 1*). A gradient was observed in the depression levels across housing sectors, where a higher proportion of social housing participants reported depression (21%), than intermediate (10%) and market-rent groups (9%). Similar proportions of participants in social housing and market-rent groups reported anxiety (33%), with a lower proportion in the intermediate group (28%). A gradient was also observed in low levels of life satisfaction across the housing sectors: 33% of social housing participants reported low levels of life satisfaction, compared with 22% of intermediate and 19% of market-rent participants. Low levels of feeling that life is worthwhile and happiness were reported similarly across the housing sectors.

Baseline mental health and well-being

Logistic regression analyses showed appreciably higher levels of depression among participants seeking social housing than in participants from the intermediate group [odds ratio (OR) 2.5, 95% CI 1.6 to 3.9] (*Table 19*, model A). The ORs were similar after adjustment for age, sex, ethnicity (model B) and marital status (model C), but marginally attenuated after adjustment for educational level (model D) and health status (model E). Levels of depression were marginally lower in the market-rent group than in the intermediate group for model A but almost identical in models B to E (see *Table 19*). The social housing sector were more likely to be anxious than those seeking intermediate housing (OR 1.3, 95% CI

TABLE 19 Odds ratios examining associations between housing sector and mental health and well-being outcomes, with the intermediate sector as the reference group

Outcome by housing sector	Model, OR (95% CI); *p*-value				
	A	B	C	D	E
Depression case					
Intermediate	1.00	1.00	1.00	1.00	1.00
Social housing	2.50 (1.61 to 3.87); < 0.001	2.32 (1.37 to 3.94); 0.002	2.34 (1.37 to 3.99); 0.002	1.95 (1.07 to 3.54); 0.03	1.89 (1.02 to 3.48); 0.04
Market-rent	0.85 (0.47 to 1.54); 0.59	0.99 (0.53 to 1.83); 0.96	0.98 (0.53 to 1.82); 0.95	0.99 (0.53 to 1.85); 0.97	1.04 (0.55 to 1.97); 0.90
Anxiety case					
Intermediate	1.00	1.00	1.00	1.00	1.00
Social housing	1.27 (0.92 to 1.75); 0.15	1.45 (0.99 to 2.13); 0.06	1.47 (1.00 to 2.16); 0.05	1.45 (0.94 to 2.25); 0.09	1.38 (0.89 to 2.13); 0.15
Market-rent	1.34 (0.90 to 2.00); 0.15	1.30 (0.88 to 1.94); 0.19	1.28 (0.86 to 1.90); 0.23	1.29 (0.87 to 1.92); 0.21	1.33 (0.89 to 1.98); 0.16
Low levels of life satisfaction					
Intermediate	1.00	1.00	1.00	1.00	1.00
Social housing	1.66 (1.20 to 2.30); 0.002	1.44 (0.98 to 2.12); 0.06	1.41 (0.96 to 2.09); 0.08	1.32 (0.85 to 2.04); 0.22	1.25 (0.81 to 1.94); 0.31
Market-rent	0.80 (0.53 to 1.23); 0.32	0.82 (0.53 to 1.26); 0.36	0.78 (0.50 to 1.20); 0.26	0.78 (0.50 to 1.20); 0.26	0.80 (0.52 to 1.24); 0.31
Low levels of feeling that life is worthwhile					
Intermediate	1.00	1.00	1.00	1.00	1.00
Social housing	1.33 (0.97 to 1.81); 0.08	1.35 (0.93 to 1.97); 0.11	1.36 (0.93 to 2.00); 0.12	1.20 (0.78 to 1.85); 0.41	1.15 (0.74 to 1.78); 0.54
Market-rent	1.15 (0.78 to 1.71); 0.48	1.13 (0.76 to 1.69); 0.54	1.09 (0.73 to 1.64); 0.67	1.09 (0.73 to 1.64); 0.66	1.12 (0.75 to 1.68); 0.58
Low levels of happiness					
Intermediate	1.00	1.00	1.00	1.00	1.00
Social housing	1.33 (0.96 to 1.84); 0.09	1.41 (0.96 to 2.08); 0.08	1.38 (0.94 to 2.04); 0.10	1.33 (0.86 to 2.06); 0.20	1.29 (0.83 to 2.01); 0.25
Market-rent	1.48 (0.99 to 2.20); 0.05	1.51 (1.01 to 2.24); 0.04	1.46 (0.98 to 2.18); 0.06	1.48 (0.99 to 2.21); 0.05	1.50 (1.01 to 2.24); 0.05

Notes
All models are $N = 1213$. ORs for depression/anxiety relate to higher scores (i.e. > 8 on scale of 0–21; ORs for life satisfaction/worthwhile/happy relate to low levels of well-being, i.e. scores < 7 on scale of 1–10). Model A: random effect for household; model B: model A plus age, sex, ethnicity; model C: model B plus living with partner; model D: model C plus education; model E: model D plus LLI.

0.9 to 1.8; model A) and ORs were slightly stronger after adjustment for age, sex, ethnicity (model B) and other covariates (models C to E). Levels of anxiety were also higher in the market-rent group than in the intermediate group, with similar ORs (OR 1.3, 95% CI 0.9 to 2.0; model A), which remained after adjustment for covariates (models B to E). Those in the social housing sector were more likely to report lower levels of life satisfaction than those participants seeking intermediate housing (OR 1.7, 95% CI 1.2 to 2.3), although this was progressively weakened by adjustment (models B to E) and was no longer statistically significant. Similarly, there were no significant differences in low levels of satisfaction between market-rent and intermediate groups. Low feelings such as 'things you do in life are worthwhile' were marginally higher in social housing and market-rent groups than in those seeking intermediate housing, but differences were not statistically significant and not materially affected by adjustment (models A to E). Low levels of happiness were higher in the social group than in the intermediate housing sector (model A, OR 1.3, 95% CI 1.0 to 1.8), and in the market-rent group compared with the intermediate housing sector (model A, OR 1.5, 95% CI 1.0 to 2.2), which remained similar after adjustment for sociodemographic factors (models B to D) and health status (model E).

Neighbourhood perceptions

There were consistent inverse associations between neighbourhood perceptions and all mental health and well-being outcomes, where better perceptions were associated with poorer mental health and well-being scores (see *Report Supplementary Material 21*). Hence, we examined the impact of further adjustment of baseline housing sector differences in depression, anxiety and well-being for neighbourhood perception scores (*Table 20*). Additional adjustment for neighbourhood perceptions of crime (see model 2, *Table 20*) and quality (see model 3, *Table 20*) weakened the higher levels of depression and other marginally higher adverse mental health/well-being outcomes among social housing participants compared with intermediate participants, suggesting that neighbourhood perceptions are a partial explanation for these housing sector differences. However, adjustment for neighbourhood perceptions had no effect on the mental health/well-being associations between market-rent and intermediate participants (see *Table 20*).

A comparison of the baseline characteristics of those who subsequently moved to East Village with those of people who did not (*Table 21*) showed little difference in mental health and well-being outcomes, overall and by housing sector. The exception was that there were higher median anxiety scores in the control group than in the East Village group among social housing participants and conversely higher levels in the East Village group than in the control group among the intermediate group. There were also baseline differences in neighbourhood perceptions by subsequent control and intervention groups. The overall baseline crime-free and quality scores were markedly higher in the control group than in those who subsequently moved to East Village; for quality, these differences were also evident by housing sector.

Follow-up

Moving to East Village was associated with small improvements in depression and anxiety scores (except for the social housing sector who showed a slight increase in anxiety), although none of these effects was statistically significant (*Table 22*). Although moving to East Village was also associated with modest improvements in well-being scores, none of the effects was statistically significant, except for life satisfaction among the intermediate sector (0.34, 95% CI 0.04 to 0.65). However, moving to East Village was strongly associated with improved neighbourhood perceptions of a crime-free and better quality neighbourhood, both overall and by housing sector. Notably, the largest effect size for improved perceptions of a crime-free neighbourhood associated with moving to East Village was observed among the social housing group (see *Table 22*).

Relating 2-year change in neighbourhood perceptions to mental health and well-being scores (see *Report Supplementary Material 22*) showed that improved crime-free and quality scores were associated with decreased levels of depression and anxiety (all p-values ≤ 0.01). Although there was less of an effect of neighbourhood perceptions on well-being scores, there was some evidence that improved perceptions of quality were related to reduced reporting of low levels of life satisfaction ($p = 0.05$) and feeling worthwhile ($p = 0.01$).

TABLE 20 Odds ratios examining associations between housing sector and depression, anxiety and well-being, adjusted for neighbourhood perceptions

Outcome by housing sector	Model, OR (95% CI); *p*-value		
	1	2	3
Depression case			
Intermediate	1.00	1.00	1.00
Social housing	1.89 (1.02 to 3.48); 0.04	1.73 (0.93 to 3.21); 0.08	1.57 (0.85 to 2.91); 0.15
Market-rent	1.04 (0.55 to 1.97); 0.90	1.05 (0.55 to 1.98); 0.89	1.05 (0.55 to 1.98); 0.89
Anxiety case			
Intermediate	1.00	1.00	1.00
Social housing	1.38 (0.89 to 2.13); 0.15	1.20 (0.78 to 1.87); 0.41	1.23 (0.79 to 1.90); 0.363
Market-rent	1.33 (0.89 to 1.98); 0.16	1.32 (0.89 to 1.96); 0.16	1.32 (0.89 to 1.96); 0.16
Low levels of life satisfaction			
Intermediate	1.00	1.00	1.00
Social housing	1.25 (0.81 to 1.94); 0.311	1.13 (0.72 to 1.77); 0.60	1.02 (0.65 to 1.61); 0.92
Market-rent	0.80 (0.52 to 1.24); 0.31	0.80 (0.51 to 1.24); 0.31	0.79 (0.51 to 1.24); 0.30
Low levels of worthwhile			
Intermediate	1.00	1.00	1.00
Social housing	1.15 (0.74 to 1.78); 0.54	1.06 (0.68 to 1.65); 0.80	0.97 (0.62 to 1.51); 0.88
Market-rent	1.12 (0.75 to 1.68); 0.58	1.12 (0.74 to 1.68); 0.59	1.11 (0.74 to 1.67); 0.61
Low levels of happiness			
Intermediate	1.00	1.00	1.00
Social housing	1.29 (0.83 to 2.01); 0.25	1.17 (0.75 to 1.83); 0.50	1.07 (0.69 to 1.66); 0.77
Market-rent	1.50 (1.01 to 2.24); 0.045	1.51 (1.00 to 2.25); 0.047	1.50 (1.01 to 2.22); 0.047

Notes
All models are $N = 1213$. ORs for depression/anxiety relate to higher scores (i.e. > 8 on scale of 0–21; ORs for life satisfaction/worthwhile/happy relate to low levels of well-being, i.e. scores < 7 on scale of 1–10). Model 1: adjusted for sex, age group, ethnic group, living with partner, education level, LLI and random effect for household; model 2: model 1 plus neighbourhood perceptions of crime; model 3: model 1 plus neighbourhood perceptions of quality.

Discussion

Baseline findings

At baseline, those seeking social housing were more likely to be depressed, anxious and less satisfied with life than those from intermediate and market-rent housing sectors. These housing sector differences in mental health and well-being outcomes appeared to be partially or wholly explained by demographic factors, including age, sex, ethnicity and partner/marital status, which are all well-recognised factors associated with psychological distress and well-being.[199,200] However, increased levels of depression among the social group persisted after adjustment for these potential confounders. This finding is consistent with a body of literature showing that those in social housing are more socioeconomically disadvantaged and at greater risk of poorer mental health outcomes, which is associated with increased stress exposures related to their surroundings.[22,201–203] Poorer well-being and neighbourhood characteristics, such as perceived levels of increased crime and decreased safety and access to green space, have all been shown to have adverse effects on depression, anxiety and well-being;[46,188,194,204] it has been suggested that prolonged

TABLE 21 Baseline mental health, well-being and neighbourhood perception scores by East Village and control groups, and by housing sector

	All housing sectors, median (IQR)			Housing sector, median (IQR)								
				Social			Intermediate			Market-rent		
Outcomes/ perceptions	Control ($N = 402$)	East Village ($N = 406$)	p-value[a]	Control ($N = 109$)	East Village ($N = 192$)	p-value[a]	Control ($N = 189$)	East Village ($N = 171$)	p-value[a]	Control ($N = 104$)	East Village ($N = 43$)	p-value[a]
Mental health and well-being												
Depression[b]	3.5 (1.2–5.8)	3.5 (1.2–5.8)	0.71	4.7 (2.3–7.0)	4.7 (2.3–7.0)	0.74	3.5 (1.2–5.8)	3.5 (1.2–4.7)	0.34	2.3 (1.2–4.7)	2.3 (1.2–3.5)	0.46
Anxiety[b]	6.0 (4.0–8.0)	5.9 (3.0–8.0)	0.71	6.0 (4.0–9.0)	5.0 (3.0–8.0)	0.03	5.0 (3.0–7.0)	6.0 (4.0–9.0)	0.02	7.0 (4.0–9.0)	5.0 (3.0–8.0)	0.29
Life satisfaction[c]	7.0 (7.0–8.0)	7.0 (6.0–8.0)	0.94	7.0 (6.0–9.0)	7.0 (6.0–9.0)	0.64	7.0 (7.0–8.0)	7.0 (6.0–8.0)	0.40	7.0 (7.0–8.0)	7.0 (7.0–8.0)	0.72
Worthwhile[c]	8.0 (7.0–9.0)	8.0 (7.0–9.0)	0.50	8.0 (7.0–9.0)	8.0 (7.0–10.0)	0.21	8.0 (7.0–9.0)	8.0 (7.0–9.0)	0.37	8.0 (7.0–8.0)	7.0 (7.0–8.0)	0.60
Happy[c]	8.0 (6.0–9.0)	8.0 (6.0–9.0)	0.40	8.0 (6.0–9.0)	8.0 (6.0–9.0)	0.54	8.0 (7.0–9.0)	8.0 (6.0–8.0)	0.08	7.0 (6.0–8.0)	7.0 (6.0–9.0)	0.72
Neighbourhood perceptions												
Crime[d]	3.0 (0.0–5.0)	2.0 (−2.0–5.0)	0.001	1.0 (−2.0–4.0)	0.0 (−3.0–3.0)	0.08	3.0 (1.0–6.0)	3.0 (0.0–6.0)	0.45	4.0 (1.0–5.5)	4.0 (2.0–7.0)	0.38
Quality[e]	5.0 (2.0–8.0)	3.0 (−1.0–6.0)	< 0.001	4.0 (1.0–7.0)	2.0 (−2.0–5.0)	<0.001	5.0 (2.0–8.0)	4.0 (0.0–7.0)	0.02	5.0 (3.0–9.0)	4.0 (1.0–6.0)	0.05

a Mann–Whitney U-tests tested for differences between control and East Village groups.
b Depression and anxiety are scored 0–21, where higher scores indicate higher depression or anxiety.
c Life satisfaction, feeling life is worthwhile and feeling happy yesterday are scored 0–10, where higher scores indicate greater levels.
d Crime scale is scored −10 to +10, where higher scores indicate less perceived crime.
e Quality scale is scored −12 to +12, where higher scores indicate higher perceived quality.

TABLE 22 Change in mental health, well-being and neighbourhood perception scores comparing change in the East Village group with the control group, overall and by housing sector

Outcome	All housing sectors (*N*=808), difference (95% CI); *p*-value	Housing sector, difference (95% CI); *p*-value		
		Social (*N* = 301)	Intermediate (*N* = 360)	Market-rent (*N* = 147)
Depression				
Model 1[a]	−0.26 (−0.65 to 0.14); 0.20	−0.35 (−1.10 to 0.40); 0.36	−0.26 (−0.80 to 0.29); 0.35	0.00 (−0.83 to 0.82); 0.99
Model 2[b]	−0.18 (−0.59 to 0.22); 0.38	−0.12 (−0.87 to 0.63); 0.76	−0.16 (−0.74 to 0.42); 0.59	0.07 (−0.79 to 0.93); 0.87
Anxiety				
Model 1[a]	−0.15 (−0.61 to 0.32); 0.54	0.45 (−0.44 to 1.34); 0.32	−0.49 (−1.10 to 0.13); 0.12	−0.45 (−1.49 to 0.59); 0.39
Model 2[b]	−0.11 (−0.59 to 0.37); 0.65	0.46 (−0.47 to 1.39); 0.33	−0.45 (−1.10 to 0.21); 0.18	−0.44 (−1.45 to 0.57); 0.39
Life satisfaction				
Model 1[a]	0.19 (−0.04 to 0.41); 0.10	0.06 (−0.38 to 0.50); 0.78	0.31 (0.03 to 0.60); 0.03	0.11 (−0.36 to 0.58); 0.64
Model 2[b]	0.17 (−0.06 to 0.40); 0.15	0.10 (−0.36 to 0.56); 0.67	0.34 (0.04 to 0.65); 0.03	0.11 (−0.37 to 0.58); 0.66
Feeling life is worthwhile				
Model 1[a]	0.07 (−0.15 to 0.28); 0.54	0.15 (−0.28 to 0.58); 0.50	0.00 (−0.28 to 0.28); 0.99	0.12 (−0.33 to 0.57); 0.59
Model 2[b]	0.06 (−0.16 to 0.29); 0.57	0.18 (−0.27 to 0.63); 0.44	0.08 (−0.21 to 0.38); 0.58	0.14 (−0.31 to 0.60); 0.53
Feeling happy yesterday				
Model 1[a]	0.21 (−0.06 to 0.48); 0.12	0.16 (−0.34 to 0.66); 0.52	0.33 (−0.05 to 0.71); 0.09	0.12 (−0.47 to 0.71); 0.69
Model 2[b]	0.19 (−0.09 to 0.46); 0.19	0.19 (−0.35 to 0.72); 0.49	0.36 (−0.05 to 0.76); 0.08	0.14 (−0.47 to 0.75); 0.65
Crime				
Model 1[a]	3.37 (2.85 to 3.90); < 0.001	4.14 (3.21 to 5.07); < 0.001	3.29 (2.55 to 4.02); < 0.001	1.85 (0.62 to 3.08); 0.003
Model 2[b]	3.36 (2.83 to 3.90); < 0.001	3.95 (2.97 to 4.94); < 0.001	3.54 (2.76 to 4.32); < 0.001	1.88 (0.64 to 3.12); 0.003
Quality				
Model 1[a]	4.91 (4.41 to 5.40); < 0.001	4.52 (3.68 to 5.37); < 0.001	5.11 (4.43 to 5.80); < 0.001	5.08 (3.81 to 6.35); <0.001
Model 2[b]	4.98 (4.48 to 5.48); < 0.001	4.40 (3.51 to 5.29); < 0.001	5.30 (4.58 to 6.03); < 0.001	5.19 (3.92 to 6.47); <0.001

a Model 1: adjusted for household as a random effect.
b Model 2: model 1 plus sex, age group and ethnic group as fixed effects.

Notes

Estimates of the difference between the East Village and the control groups are from multilevel models and are the change in the East Village group compared with the change in the control group. The model for all housing sectors is also adjusted for housing sector.

exposure to poor-quality neighbourhoods may have an amplifying effect.[205] Our results show that positive perceptions of neighbourhoods being crime-free and quality appeared to reduce levels of depression (as well as moderating non-significant associations with anxiety and poorer well-being) among those in the social sector compared with those seeking intermediate housing, suggesting that the negative neighbourhood perceptions observed among those seeking social housing may partly contribute to the higher levels of depression within this group. It was noteworthy that the sociodemographic characteristics of those seeking market-rent and intermediate accommodation were similar, and there were little differences in mental health and well-being except in having a marginally lower prevalence of feeling happy the previous day among the market-rent group. Allowing for neighbourhood perceptions attenuated these modest differences in levels of happiness and, unsurprisingly, did not alter the similarities in other mental health and well-being-related outcomes.

The differences observed with the social sector demonstrate the potential importance of the built environment on mental health among the more disadvantaged, which is entirely consistent with a body of literature showing the effect of the built environment on depression, anxiety and well-being.[153,187,204] Hence, it remains entirely plausible that the mental health outcomes of those affected by poorer surroundings might be improved by moving people into environments that encourage positive well-being,[206] which longitudinal follow-up of the ENABLE London cohort was able to examine.

Follow-up findings

Despite observing sizeable improvements in objective measures of the built environment (see *Chapter 3*) and neighbourhood perceptions associated with moving to East Village, particularly in the social sector where there were marked improvements in perceptions of a crime-free neighbourhood, there was little evidence of improved mental health and well-being outcomes after 2 years (although there was a modest improvement in life satisfaction among those living in intermediate East Village accommodation).

Unfortunately, there is very limited literature to put these study findings in context, as few longitudinal studies have examined the long-term effects of urban regeneration schemes on health, and even fewer have examined effects specifically on mental health and well-being-related outcomes.[207] One notable exception is a large-scale experimental study carried out in five US cities, the Moving to Opportunity (MTO) study, which examined the long-term effect of being randomised to receive or not receive housing vouchers to encourage moving from high- to low-poverty neighbourhoods on the physical and mental health of 4606 minority low-income families.[208–210] Although improvements in living conditions among the intervention group were demonstrated over a 10- to 15-year period, there was little difference in adult mental health-related outcomes and economic self-sufficiency between groups, although a small improvement in subjective well-being associated with moving to less deprived neighbourhoods was observed.[206,208] However, there were mixed effects among the participants' offspring. There was evidence of increased rates of depression, stress and conduct disorders at follow-up among teenage boys who moved to less deprived areas but, conversely, reduced rates of conduct disorders among girls.[210] Other more direct evaluations of urban regeneration schemes in Spain[211] and the Netherlands[212] have shown little effect on mental health outcomes from after 3[211] to 5 years.[212] From a UK perspective, a large long-term housing improvement programme in Glasgow, Scotland, showed a small positive effect on mental health scores after 2 years[213] and found that mental health scores in the most deprived areas that received higher levels of investment improved more after 5 years than lower investment areas.[214] However, effects were small and less favourable findings showed that the scheme may have actually increased fear of crime, as relocation may have disturbed established social networks.[215] Other UK studies that have examined the effect of urban regeneration programmes, including change in the built environment, have also shown little effect on mental health and well being outcomes, although change in the built environment has not always been well defined.[216] The closest study to ours geographically also used a natural experiment to examine the effect of London Olympic regeneration among 2254 children attending secondary schools across the London Borough of Newham, compared with pupils attending schools in other east London boroughs. They found no effect of urban regeneration on self-reported

physical activity, mental health and well-being outcomes after 18 months, and repeated cross-sectional surveys among 995 parents suggested that levels of anxiety and depressive symptoms might have increased as opposed to decreased in Newham, compared with control areas.[217]

In summary, the effects of urban regeneration on mental health-related outcomes appears modest at best and mixed, not applying equally across population groups. Our finding that moving to East Village did not have any sizeable effect on mental health/well-being-related outcomes is entirely consistent with these studies, suggesting that more needs to be done to demonstrate the effect of change in the local environment on mental health and well-being, and to understand why greater differences are not observed.[96]

The ENABLE London study was carried out to provide robust evidence of the effect of the built environment on health (particularly in a UK context). However, a key limitation is that the mental health and well-being outcomes were secondary to the main hypothesis of the study (where the primary outcome was physical activity) and lacked statistical power. Moreover, the staged recruitment, whereby those in social housing were moved in before those in other housing types, before the East Village development was fully complete, may have dampened exposure effects and not allowed sufficient time for social networks to become established. Although no appreciable changes in physical activity and adiposity outcomes were observed (see *Chapter 3*), which could have plausibly affected mental health and well-being, it remains possible that longer-term follow-up may demonstrate significant effects. However, this seems unlikely given the modest effects on mental health and well-being outcomes observed after 2 years and that continued development of the area, including high-rise accommodation blocks and reductions in green space,[218] could potentially lead to adverse effects (see *Chapter 9*).

Despite the growing need for more housing, particularly in major cities, opportunities to examine the potential health impact of such developments are limited. It is widely accepted that area regeneration programmes should be designed to have positive impacts on its residents, as well as reducing health inequalities.[219,220] However, it is challenging to create high-density urban environments with appropriate local facilities to promote positive health behaviours while also protecting residents from the potentially adverse effects of high-density housing.[221] There is little understanding of what is considered to be the optimum density to encourage social contact while moderating other exposures, especially among the more disadvantaged.[153] Further research is needed to establish how people from different socioeconomic backgrounds living in the same neighbourhood interact with each other and their local built environment to identify specific aspects that may be contributing to poorer health. Such studies will inform the planning and design of housing developments for improved mental health and well-being.

Chapter 7 Qualitative data from the ENABLE London study

Previous work has indicated that there were limited positive effects of the London 2012 Olympic and Paralympic Games on the most disadvantaged residents of the Olympic boroughs. An important part of the legacy of the London Games was the conversion of the Athletes' Village into East Village, which was designed on active living principles and aimed to provide social, intermediate (affordable) and market-rent housing. The ENABLE London study investigated the effect of moving to this new environment on levels of physical activity among individuals from all housing sectors. The present analysis is based on focus group discussion with the social housing residents of East Village. Participants were asked about personal the social and environmental influences on their levels of physical activity and their use of local recreational space and facilities. Participants were positive about their new homes and the safer neighbourhood; however, they also complained about the high cost of living, restrictions on children's play areas and limited facilities for older children/teenagers. The high costs, in particular, had a strong impact on participants' plans to continue living in the development. These concerns need to be addressed to ensure a sustainable community.

Introduction

Defining and understanding the legacy of large events such as the Olympics is complex and can encompass elements of economics, built environment and sustainability.[222] 'Soft' or non-infrastructural elements of a legacy include individual-level changes to mental and physical health and skills development, as well as community-level changes such as increased social cohesion.[223] The bid for the London 2012 Olympics emphasised legacy.[224] The Olympic Games were positioned as an opportunity to tackle the problems of London's East End, which included deprivation, unemployment, poor health outcomes and a shortage of housing, by driving regeneration and through increased investment.[225]

High-quality evidence supporting the role of major sporting events in delivering a tangible (infrastructural) or non-infrastructural legacy is limited.[223,226] Evaluations of the London 2012 Olympics also suggest that there was little positive impact on the most disadvantaged residents of these boroughs. Previous research has noted that the housing legacy of the London Olympic Games has fallen short of its ambitions; this appears particularly true in the case of social housing provision.[227] Indeed, development and gentrification has led to the decanting of existing communities to make way for Olympic facilities,[228] the growth of developments that are perceived by the local population as 'not for them'[229] and the displacement of residents as a result of the increases in rent and house prices.[227] In terms of a health legacy, studies have failed to find sustained health improvements in the area.[217,230,231]

Although several studies have examined the effect of the Games on residents of the Olympics boroughs, there has been relatively little research examining the views of residents of the new East Village. The Speaking Out of Place project[232] interviewed tenants from the social, intermediate and market-rent groups in East Village, in addition to individuals with a community role in East Village and residents from neighbouring areas. Their analysis found a growing sense of community among residents, although there were tensions around the high levels of securitisation and control. Both social housing and intermediate housing tenants reported concerns about the high costs of living in the neighbourhood and insecure tenancies.[232] In contrast, Wilson's[233] work found relatively little interaction between residents, which was largely confined to individuals living in the same block. The work also suggested that certain features of the built environment in East Village may serve to limit interactions between different housing tenures.[233]

This chapter presents an analysis on the experiences of social housing tenants who moved into East Village.

Methods

The focus group was conducted in 2015 among social housing tenants approximately 1 year after they had moved to East Village, and aimed to identify factors relevant to the built environment and health that had not been covered or were inadequately covered by the baseline questionnaire used in the study. It was expected that findings from this focus group would provide additional context to the findings, as well as inform the spatial narratives work that would be carried out (see *Chapter 8*). Although the initial proposal included carrying out focus groups with members of the social and the intermediate housing sectors, time constraints meant that only social housing sector participants were contacted as they were the first group to move into East Village.

The focus groups were conducted using established procedures,[234] audio-recorded and transcribed. The focus group started with a free discussion by participants regarding their experiences of living in East Village. As the discussion progressed, additional topics such as community cohesion, transport, traffic, noise, parking, safety, shopping, and the levels of exercise and use of local parks, gyms and swimming pools (including use of the Olympic Park) were introduced by the facilitator. All transcripts were anonymised. Following this, a thematic analysis[235] was used to identify the main themes from the content of the focus group transcripts. This involved reading and rereading the transcripts and grouping data extracts together according to their main themes. A coding framework was developed, based on emergent themes, which identified the major topics and issues.

Eighty ENABLE London study participants who took part in the follow-up assessments between January 2015 and June 2015 were asked if they would be interested in taking part in the focus group. A total of 75 individuals from 65 households expressed an interest and were sent a formal invitation letter in July 2015. Thirteen households agreed to take part and were sent a further invitation letter with three suggested dates. The most popular date of participant availability was determined. Eleven individuals from separate households agreed to attend the focus group. On the day, seven attended; two confirmed that they were not able to attend and there were two no-shows. The participants were three black females (aged 32 years, 45 years and 39 years), two Asian females (aged 43 years and 45 years), one mixed ethnic origin female (47 years) and one white male (45 years). Five participants lived in Newham prior to moving into East Village; of the remaining two participants, one lived in Hackney and the other lived in Tower Hamlets. The focus group was conducted at a local school (Chobham Academy, E20) in August 2015 and lasted 100 minutes. East Village residents had been living in their new homes for 12–18 months. Five participants were in employment, one was a student and one was unemployed because of ill health. Shopping voucher incentives were given to those who participated.

Results

Five themes emerged from the analysis of the focus group transcript: (1) 'cost of living', (2) perception of new home, (3) perceptions of the neighbourhood, (4) sense of community and (5) healthy living. Quotations are identified using unique initials for each participant and their gender.

Cost of living

Participants commented on issues around the expense of living in an area of London that is undergoing rapid redevelopment and gentrification. They were concerned about the higher costs associated with living in the new development, including higher costs of basic utilities and council tax, which meant they were unable to save:

> *My first thing is the expense. I can't save. Whereas in my other house, I could save. I can't save at all. Obviously, it's a band D area, I wasn't in a band D, so council tax has gone up, the rent has gone up. I'm paying for water. I'm paying to heat my water. I'm paying the electricity. I'm paying to clean my communal area.*

> *It's too much. I can't save. I have to pick and choose the brands I buy in the supermarket to try and keep my costs down. I'm more financially strained now.*
>
> *A, female*

> *And to compare with what we were paying before and here . . . my water bill has gone by, I'd say about 70%, so that's a lot . . . We were told it was going to be a decrease. One of the reasons I chose the house is that it would be 25% less living cost compared to where we were living. So I thought, 'Oh! 25%. That's quite a bit.' But actually it's about 50% increase.*
>
> *B, female*

The high costs were cited by residents as a major reason why they would not consider living in East Village long term:

> *I don't see myself living here. With my children. It's a lot of expensive. You can't save money.*
>
> *C, female*

> *. . . more and more expensive, I just think, oh right, because they say it's the East Village, I don't know if you're paying because of all the re-development they've done, we're now paying for it, umm, but it wouldn't be feasible to live here long term, if it carries on.*
>
> *G, female*

Amenities such as shopping facilities were limited for the social housing sector who were the first to move to East Village. The residents did not really use the Westfield Shopping Centre, which forms a gateway to the Olympic Park, citing expense as the main barrier. Many reported going to shops near their former residence:

> *And it's funny to say, I don't shop at Westfield, I do go around, just to browse around. I'll probably go to some of my familiar shops to do you know like clothes shopping and stuff, but I don't buy my groceries . . .*
>
> *F, female*

> *Waitrose did until umm Sainsbury's opened. It did get used but I used to find– I've got grown-up adults children, who are eating for the world, I would go in there and get like two bags and it would be like £20/£30 and that was nearly enough every day . . . Oh my God, I thought, I can't live here.*
>
> *B, female*

Perceptions of new home

East Village residents were generally happy and reported a sense of pride in their new homes. Many noted that there was a greater sense of calm in their new homes associated with better family space and family members having more of their own space. Better ventilation, no damp and brighter homes were all noted as positives:

> *The positive is because my children are older they've got their own rooms now. We've got a bigger kitchen . . . and now the whole family can sit down around the table. We have a family meal every day, whereas before it was once every so often. So it's brought us closer . . . This place is cleaner. The area is cleaner compared to where I lived before. . . . there are a lot of positives. Everyone's calmer. It makes the family a little bit more calmer. Also, they're very proud: it's a nice place to live. They feel happy.*
>
> *B, female*

> *I'm quite happy here. It's bigger and the children are a lot more happier here . . . I feel secure in here because the security is 24 hours . . . We have a bigger kitchen now and we have family meals every day now, we eat together. They've all got their own rooms. So we [are] calm.*
>
> *D, female*

> *Anyway, I live in a townhouse and I found the place very good. As you said the ventilation is excellent in the house. The rooms are big and everything. About the house I've got no issues with the house, it's just excellent.*
>
> *D, female*

Despite this, the families also had some complaints about the new homes. Individuals in the flats complained that there were limited storage options and strict rules regarding where they were allowed to store items. A further complaint centred around rules for the social housing tenants, which stated that they were not allowed to personalise their flats, including adding curtains to the windows, which had an impact on privacy:

> *Most of the proportions are– once you put a wardrobe and a chest of drawers in it's really tight.*
>
> *E, male*

> *I must say that what we've said about storage, the storage was better in my old house because I did– I'm not necessarily a hoarder, but I have things that I know that, for example, we will use in the summer, whereas now I had to buy storage, I had to buy a big storage to put on my balcony. I've had to buy storage containers to put in my hallway. I've had to buy another big shoe storage to put– I've had to spend loads of money, hundreds of pounds, just to– because I'm a believer that umm everything should have a home and I don't like clutter, so if it's out of order, I throw it in the bin, and obviously– so as I said storage is a big problem. Can't store my buggies anywhere whereas in my old house we had like a downstairs sort of like cupboard where we could store stuff.*
>
> *A, female*

Perceptions of the neighbourhood

Overall, participants were very positive about their new neighbourhood, in particular commenting on the cleanliness, order and greater security compared with where they lived before:

> *That's really nice actually. I think the greenery is lovely. The greenery is lovely. The way that like we're close to transport, close to Westfield, all of that's nice as well. The streets are clean. I like the way that they have tried to upkeep the cleanliness of the area as well, you don't hardly see any garbage on the streets. Even down to– well I haven't experienced it, like unruly kids on the street, like– you know you get normally like people hanging around, because that was my fear here, was coming here and having like little kids hanging around, gangs hanging around, or whatever, because of the way that the community is laid out, but I haven't experienced any of that, I haven't seen any of that yet.*
>
> *A, female*

However, participants also reported certain frustrations with the development. In particular, many of the social housing tenants had young children and they were concerned about the number of restrictions on children's play areas. Despite having access to the playing areas in the Olympic Park, many parents felt that those areas were too far away for their young children to go to alone or to play in unsupervised:

> *I feel that there is a lot of restriction, so children cannot, for example, play ball games, ride bikes in the terrace. If they have to they have to go to different parts, even though the parks are not so far, but it requires leaving everything.*
>
> *F, female*

The issue of limited facilities to keep teenagers engaged was also noted by the residents. Participants were concerned that as children grow up, there would be little for them to do, which could lead to antisocial behaviour. This was a major source of worry for these parents, and would be very likely to have an impact on their decision to stay on in the development:

> *I think also like for my daughter, who is a teenager, what we were saying before, there's not much in the area for them to do, apart from going to Drapers Fields and I think there should be like a little community*

thing where they can do things like table tennis and– under supervision, you know, like after school, because my daughter does get bored. She just– in my area, in my block, in the community, there's a lot of young children, not much children her age, and I've noticed that children who come to the school that do live in the area umm I don't know, it's like they are forced to argue. Because they don't really have much to do, a lot of the time my daughter's on her tablet, with people in the area, umm, abusing each other, and I think if they– yes, no, but seriously, there's no sense of cohesion with the teenagers in the community. There's a sense of cohesion with the small ones, but me personally– and a lot of the time I see them sitting on the steps and stuff like that, as I was saying about finding the condom in the sand pit area, they are doing things like that, whereas if there was something positive that they can go to . . .

A, female

People hanging around on the staircases, it's going to get worse and worse and especially if they don't build a communal area for the teenagers, it's going to get worse and worse. They've only built it up for young children. So that's one thing that I'm dreading in the future and that's one reason, another reason, why I'd want to leave as well is . . .

A, female

Sense of community

Participants' relationships with their neighbours were generally positive. The management was also active in organising a range of activities for residents to meet each other and managers. However, it appeared that only a few were aware of or had made use of facilities organised by the management:

Well my neighbours are really really nice. My neighbours on my floor are really really nice because we send each other Christmas cards, even when I had my daughter, they sent me gifts, etc. That's really good. I must say that I don't– I know there's a lot of community things going on and they display it on the boards in the flats, but I don't make use of them personally, so I can't really.

A, female

Encouraging healthy living

East Village was designed to encourage healthy living and has access to gym and sports facilities in the Village and nearby Olympic Park, as well as the swimming facilities in the Aquatics Centre. Parents with young children felt that facilities for children to play should be made available closer to the houses. A few concerns were also raised regarding security in the available play areas:

And we've got so much open space, I think for children, they should do something– like a proper park, with swings, a slide, things like that, because they don't want you to use the communal gardens, so they should provide a little local park for them.

G, female

In comparison to my old house we had like, as we said, a little park, where my child could go to. Here you've got little bits of parks, here and there, which is a bit of a bummer and I don't think some of the parks are controlled very well around here, whereas in my old house, they were very very controlled . . .

A, female

Overall, experiences with increasing physical activity were mixed. Participants were often unaware of the facilities available to them and many reported not using them. In certain cases the lack of local shops made it necessary for people to travel further away to buy things, which meant they were more likely to drive or use public transport rather than walk, therefore reducing their physical activity:

Umm I would say mine is the opposite. Umm– because where I used to live before, umm, you could walk to like the local shops, etc. I know I've got Sainsbury's now but sometimes if you want something elsewhere, I used to like umm– because of my culture we buy certain foods that we can't buy in

Sainsbury's, but I used to have shops close to me that I could just walk to, but now I have to drive to work to get those things, so I won't walk, I will just take the car, so it's restricting me, umm, I don't walk as much in that sense now . . . The only difference I would say is walking from my house to the car park, that's probably the only thing that's changed, because in my other house, I could just walk outside my house and my car would be there, so in terms of physical activity, no.

A, female

I think I've gained some weight since I have moved from my old address to this new address and that's partly because, what you just said, I drive around as well, I don't– because I find things a bit far, I mean, where I was in my old home before, I could go to my work, because I work in the school as well, that's part time. I used to take a walk to the children's centre but now I can't take a walk, it's quite far, so if I have to get to my children's centre, I have to drive.

F, female

Umm I'm less active. Because where I lived before I used to walk to work, walk home, now I have to get a bus.

G, female

Others reported using the facilities to a greater extent and encouraging their children to do the same:

I do make use of the– because I go to the gyms as well there and the swimming. I get the kids involved. I've got a 12-year-old who has put on a bit of weight since we moved in here. He actually put on weight when we moved here, so I said, right, swimming, basketball, table tennis, these are all free for him, so I said right, I'm registering you in to everything and then what we do we go there, weather's good, soon as I'm finished from here that's what I'm getting ready to go, we will sit and spend the whole day there.

B, female

Well for me, my activity is because I have to walk more. Before I was not. Because the parking (. . .) to leave your car at work because when you move your car, when you come back, there won't be parking, so why don't you leave it here, walk, just across the other side of Stratford and go to work, so health-wise I've seen a lot concerning my life and the children and then, umm, the rest I don't know the rest but for me it works for me.

C, female

As East Village was designed to encourage active living, there are restrictions on parking and limited availability of parking spaces. Although residents were made aware of this, some participants, particularly those with large families or with health problems, found this restriction limiting:

The only problem is the parking because I can leave my car and go to work, but when it comes to shopping, as a family of five children, there's no way you can do shopping by bus or train, so you need that car, but sometimes I have to wait to go shopping, you can't have a place to park, even though you have a free parking along there, outside, or– so you have to pay the inside one, which is £60 a month, which is very, very expensive for a mother of five, so that's the only problem, apart from that I'm really enjoying the place.

C, female

I needed my car, but coming here, because I never had two children under the age of 10, I wasn't allocated free parking, which was horrible, I mean I've had parking tickets, I mean the parking guidelines are not clear here, as well . . . I wasn't allocated underground parking, which was obviously a thing, and now I've got another daughter as well, so it's a big problem, so I have to pay £65 Stratford International to park my car every month.

A, female

> *I gave my car up just as we moved in, umm, because I wasn't allowed– I applied for the parking, I didn't get it, and you know, the one that you get with the underground, and at that time, I actually didn't know about the council parking, because I did ask about that, and all they told me about was the parking that you know the Triathlon– the East Village parking so I wasn't aware of [whether] we was going to get a council parking, afterwards, because the first car is free, so I got rid of my car, so I do find shopping is a little bit hard, because I've got umm early-onset arthritis and to carry shopping from anywhere it's a bit difficult, but I mean, I suppose we do online shopping and get them in somehow.*
>
> *B, female*

Discussion

Residents of the new East Village had largely positive views about their new homes and enjoyed the security and cleanliness of the neighbourhood. Although participants in the focus group were largely unaware of, or did not choose to participate in, many community events, they reported good relationships with their neighbours. Most participants were, however, quite concerned about the high costs of living in East Village. Quantitative analyses of the ENABLE London study data suggest that there were no significant improvements in physical activity levels (see *Chapter 3*) or well-being (see *Chapter 6*) of participants associated with moving to East Village.[66] Furthermore, the quantitative analysis showed that the residents perceived the new neighbourhood to be of a better quality and as having less crime than the areas where they previously lived.[66] These findings are broadly supported by the focus group data. Findings from the focus group analysis also support the results of the Speaking Out of Place project, which noted that organised community activities as well as tenants' groups were contributing to the building of social networks and a growing sense of community solidarity.[232]

The social housing sector was the first to move into the new development; however, many facilities such as nearby shops were not yet open. These amenities are now available in East Village (see *Chapter 9*). Analysis of the focus group data indicates that many of the participants found costs associated with living in the new housing development to be prohibitive and in some cases individuals felt that they were getting less for their money than with their previous accommodation. Many facilities that were available were also unaffordable. This had clear implications for the participants' shopping in the local area, which discourages a sense of community. Many commercial developments in East Village appear to target wealthier residents.[233] Exclusions because of affordability were also noted in the Speaking Out of Place project.[232] The findings highlight existing uncertainties around mixed-tenure developments, in which many facilities or nearby developments may not be affordable to residents on lower incomes.[236]

Another difficulty cited by participants related to the provision of facilities for children. Many felt that parks were too far away for young children to access and the areas near their homes had strict play times and restrictions imposed on children's play areas. The social housing residents were also concerned about the availability of activities for older children, particularly teenagers, and were worried that as their children grew up the lack of facilities would mean boredom and possible antisocial behaviour. Previous work has noted the 'sterile' quality of the East Village neighbourhood brought about by the strict policies regarding cleanliness, playing areas and noise enforced by the management, which do appear to find some support from the private renters who complained about noisy children.[232,237]

The lack of nearby play areas for children and limited local shops led to a decrease in physical activity for some participants. Many were also unaware of discounts at the Olympic Park facilities that were available to them. Findings from the quantitative analysis in the ENABLE London study suggest that participants in social housing were closer to a park in East Village than they were in their previous houses, with walkability and access to public transport also higher in East Village.[66] However, when the social housing tenants first moved into the development many amenities such as the parks were still

being developed, and access to certain areas might have been limited. Later work examining the use of shared spaces in East Village found that the presence of high-end stores around one of the largest parks led some social housing tenants to believe that the park was solely for the use of the market-rent tenants,[233] suggesting that certain design features may inadvertently stop individuals from using these amenities. Although the limited parking led to increases in walking for some members, others found this to be very inconvenient and an added cost. Planned developments, including building on existing green space, may lead to a further decrease in activity levels.[218]

Our analyses are limited by the fact that we carried out only a single focus group with social housing tenants from East Village; additional focus groups would have been able to provide us with a fuller picture of life in East Village for this housing sector. Additionally, carrying out focus groups with participants from the intermediate and market-rent sectors would have allowed us to better understand how the different housing sectors experience their environment.

Conclusions

The Olympics represented an opportunity to have an impact on the social and structural determinants of health in a deprived part of London;[224] however, the housing legacy of the London Olympic Games has fallen short of its ambitions.[227] We and others have identified many positives associated with the social housing in East Village; however, concerns regarding affordability and facilities for children need to be addressed to ensure a sustainable community with health benefits for all.

Chapter 8 Qualitative data: using spatial narratives to explore how relocating to East Village influenced perceptions of the environment and active travel decision-making

Introduction

Physical activity is not represented by a single behaviour; it is an outcome underpinned by a series of behaviours, which may have different determinants. In adults, these behaviours or domains commonly include occupational (work-related), domestic (household, active child care, chores), work transportation (walking or cycling for commuting), non-work transportation (non-work walking or cycling trips) and leisure time (discretionary or recreational time, active hobbies, sports and exercise). These domains are also not exclusive; for example, walking or cycling to shops to buy food combines two domains (non-work transport and domestic). For a move to a new neighbourhood to influence physical activity, it must increase activity in these domains by influencing their domain-specific determinants either directly or indirectly.[238] New opportunities to take up active travel or change from passive to active travel can particularly increase daily levels of physical activity. For example, Sahlqvist *et al.*[239] reported that, after controlling for differences in demographic characteristics, adults who used active travel (i.e. walking or cycling) for either commuting purposes or non-commuting purposes engaged in an additional 321 and 279 minutes of self-reported physical activity per week, respectively, compared with individuals who travelled solely by motorised transportation. The combined use of active and motorised travel was also associated with greater physical activity than exclusively motorised travel. Prospectively, a positive change in active travel was related to an increase in total physical activity, in part because it was not related to a decrease in recreational physical activity.[240] Similar studies based on objective measures of physical activity highlight the importance of active travel for adult physical activity, which contributes on average nearly half of total weekday MVPA (47.3%). This represents a 60% difference in physical activity between those who do and those who do not use active forms of transport.[241] Furthermore, 11.25 metabolic equivalent hours per week of walking or cycling (akin to meeting the current recommendation of 150 minutes of moderate intensity activity per week) is associated with a reduced risk of all-cause mortality of one-tenth. This relationship held after adjusting for leisure-time physical activity, emphasising the value of promoting transport-related and leisure-time physical activity for health.

However, there are significant barriers to sustainably increasing physical activity in adults for both leisure-related and transport-related activity. For leisure-time or recreational activity, these include lack of facilities and time, feeling too tired or weak and having no one to exercise with.[242] Environmental barriers are particularly influential for transport-related activity: high traffic volume and speeds, distance to amenities, lack of pavements or cycle infrastructure, and unpleasant surroundings all dissuade individuals from walking and cycling.[238]

Aspects of environmental design can help to increase levels of active commuting. Grid-based street layouts lend themselves more to walkability[243] and cycle lanes segregated from motorised traffic can encourage more people to use bicycles.[244] Long-term policies to develop cycling-friendly infrastructure in European countries have resulted in increased cycling journeys and improved health and productivity.[245] Positive policy determinants include a mixture of hard and soft measures, ranging from laws relating to speed limits and urban design favouring bicycle transport to education and car-sharing initiatives. In addition, policy decisions involve consulting the population on their wishes and concerns about cycling before implementation.[246]

In more recent policy recommendations, UK policy now includes environmental approaches to increase physical activity such as recommendations to promote urban design that encourage active travel at all levels, including transport and regeneration planning, in both urban and rural areas.[247] Research from the RESIDE study in Perth, Western Australia, supports evidence for considering the wider environmental levels of influence on active travel.[94] After relocating to a new area, both transport and recreational walking changed in response to local transport provision, local facilities and attractiveness of the area. Over the first 12 months after relocating, transport walking declined overall but those with a greater number of destinations such as places of work, schools and green spaces increased their transport walking on average by 6 minutes per week with an additional 3 minutes per week for each additional local facility.

In addition to using objective measures to assess the use of the environment and the environmental elements most related to physical activity, qualitative data can add important complementary information. Qualitative enquiry can highlight the most salient perceptions for individuals, provide a temporal frame beyond the short-term objective measures of behaviour and provide additional contextual information that can help explain behaviour as well as the complex interactions between determinants, which is not possible with quantitative data. Qualitative semistructured interviews were carried out with a group of the ENABLE London study participants living in East Village[61] to investigate their perceptions of the new environment compared with their previous neighbourhood, and how these environmental factors influenced subsequent transport-related and leisure-related decisions and behaviours. These analyses, therefore, sought to investigate whether or not moving to the East Village resulted in improved perceptions of the environment and whether or not this influenced levels of activity in different domains, particularly transportation and leisure-time domains.

The East Village development has housing in blocks of apartments, with green areas and pathways among the buildings. It is situated next to the Queen Elizabeth Park, also built for the 2012 Olympic Games, which includes various leisure facilities that are open to the public and a large area of parkland known as the Waterglades (*Figure 5*). The design of the development included deliberate restriction

FIGURE 5 The East Village development.

of car parking, extensive bicycle lanes and storage in the form of outdoor stands, as well as various exercise classes and similar activities available to residents free of charge. There are numerous shops and eateries in close proximity to the residential accommodation, as well as an underground station at Stratford and a station for the Docklands Light Railway. There is a very large nearby shopping centre known as Westfield, which is situated between the apartment block complex and the Stratford underground station; security guards patrol the development regularly. The area also includes world-class sports venues [main stadium, aquatics centre, velodrome, BMX (bicycle motorcross) and mountain-bike tracks, road and cycle routes]. In comparison, the type of neighbourhoods from which these participants moved can be seen in *Figure 6*.

Methods

Design

This was a qualitative study based on an analysis of semistructured interview data generated with individuals living in East Village.

Participants and sampling

Purposeful recruitment was used to select participants with regard to change in travel behaviour over a 2-year period based on measures derived via an algorithm developed for the ENABLE London study, which used GPS, accelerometry and GIS measures (see *Chapter 5*).[166] Participants eligible for recruitment were selected on the following basis:

- They all were living in East Village at the follow-up interview.
- They met the ActiGraph compliance threshold at both phases (including ≥ 1 day at both time points).
- Participants from all housing sectors were included (social, $n = 40$; intermediate, $n = 92$; and market-rent, $n = 14$ adults).
- Information on age, sex and ethnicity was also provided.

FIGURE 6 Street of terraced housing in Newham. ©2020 Google.

From this sampling frame, three groups were targeted based on change in travel behaviour:

1. Those who were in the lowest quartile for the proportion of time spent in active travel at baseline and who had increased the proportion of time spent in active travel (walking and/or cycling) by ≥ 5%.
2. Those who were in the lowest quartile for active travel but did not change the proportion of their time spent in active travel over the 2-year period.
3. Those who decreased the time spent in active travel by ≥ 5% over the 2-year period.

Participants from the control group were not invited, as comparing perceptions of new and old neighbourhoods and the change in travel behaviour in response to the move was a key element of data generation. Exclusion criteria were limited to anyone who was non-English-speaking and all participants were offered a voucher incentive. All participants were given information about the study and gave their written consent before interviews took place, including for the recording of the interview. Focusing on those in the lowest activity levels is important because they potentially have the most to gain; for example, Kelly *et al.*[248] found in their systematic review that reduced risk of all-cause mortality was greatest in individuals with the lowest levels of activity (i.e. ≤ 120 minutes of walking or ≤ 101 minutes of cycling per week).

Qualitative data generation

Semistructured interviews were conducted in participants' homes between November 2017 and January 2018 by two experienced qualitative researchers (Rachel Hahn and Bina Ram). The responses were recorded on a digital recorder, transcribed verbatim, anonymised and stored on a University of Bristol secure server before being imported into NVivo10 (QSR International, Warrington, UK) for data organisation. The interview schedule was based around comparative perceptions of individuals' old and new neighbourhoods, aspects of everyday travel and leisure and how moving to the East Village had influenced this (see *Appendix 2* for the questionnaire used). This study provided a unique opportunity to use individual travel patterns, which were generated by a programme using GPS, accelerometry and GIS data as part of the ENABLE London study[166] to provide the framework for a spatial narrative whereby residents could describe their routines, influences and decision-making within a spatial framework. Individual maps were generated for the interviews, which described patterns and places before and after moving to East Village. The interview schedule was developed in discussion between a researcher from the ENABLE London study (AP), a PhD student who was analysing interviews as part of her PhD (ER) and the researcher who conducted the majority of the interviews (RH). Interviews were structured to take no longer than 45 minutes (see *Appendix 2* for the interview schedule). One-to-one interviews were selected as the method of inquiry because of the highly variable activity patterns of individuals, which meant that the interviews could be tailored more effectively.

Data analysis

For the purposes of this analysis, inductive thematic analysis was used.[235] Inductive thematic analysis followed the six steps outlined in *Figure 7* and themes were generated from the data inductively rather than by imposing a predetermined coding framework.

Results

Table 23 outlines characteristics of the 26 participants who agreed to be interviewed. Overall for the increase in active travel and no change in active travel groups, there was good representation from the social and intermediate housing sectors and by gender and ethnicity. The profile was different for the decrease in active travel group but was representative of the smaller pool eligible for invite, whereby the majority of participants who were active at baseline but decreased their activity by at

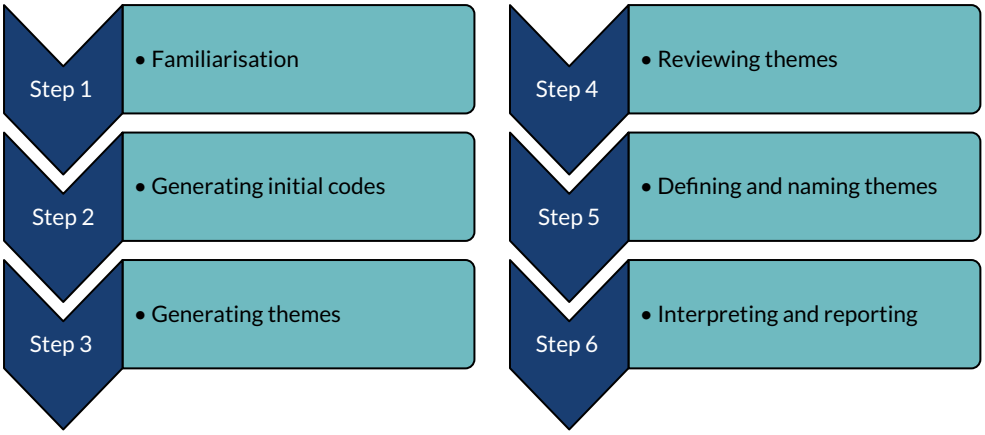

FIGURE 7 Thematic analysis steps. Information sourced from Braun and Clarke.[235]

TABLE 23 Characteristics of the 26 participants interviewed for the spatial narratives

Characteristic	Active travel		
	Increased ($n = 10$)	No change ($n = 9$)	Decreased ($n = 6$)
***Housing* (n)**			
Intermediate	5	4	4
Social	5	5	2
***Gender* (n)**			
Female	6	4	2
Male	4	5	4
Age (years)			
Range	24–54	26–49	19–32
Mean	38.6	32.4	29.1
***Ethnicity* (n)**			
White	6	5	5
Black/African/Caribbean/British	4	1	1
Mixed/multi	0	1	0
Asian	0	2	0

Increased active travel: increased from low active travel (walking and cycling) at baseline to the top quintile at follow-up; no change in active travel: in the bottom quintile for active travel at both baseline and follow-up; decreased active travel: decreased walking/cycling by ≥ 5% from baseline to follow-up.

least 5% were from the intermediate housing sector, male, white and relatively young. Across all three groups the age of participants represented a relatively narrow range, which skewed towards younger participants. The market-rent sector was under-represented in the sample largely owing to the small number who met the eligibility criteria.

Perceptions of the environment and relationships with physical activity

The majority of participants generally expressed more positive perceptions of their new built environment in the East Village irrespective of gender, type of housing or whether or not their travel had changed since

moving to East Village. The initial preliminary themes generated from the interviews are extracted and summarised below in relation to change in four key features of the built environment: *Functional features*, *Feeling safer*, *Aesthetics* and *Destination features*. This structure allows interpretation in relation to existing frameworks[249] and the most contemporary systematic review on qualitative studies on the perceptions of the built environment and physical activity in adults.[250] Examples of functional features include direct routes, street and path design and maintenance, traffic control and vehicle parking. Safety features include surveillance, crossing aids and lighting. Aesthetic features include cleanliness, interesting sights, maintenance, greenery, architecture, noise and pollution. Destination features include proximity, accesses and availability of local facilities, green spaces, shops, health care, sports facilities, parking facilities, public transport and other destinations.

Functional features

The main functional feature that emerged from the interviews was parking and its impact on regular access to a car. Perceptions on the feasibility of owning a car varied. Negative perceptions included:

> *Now if you have a car, it's a problem, the biggest problem is having a car here.*
>
> *F (female), SH (social housing), NC (no change activity group)*

> *It's too expensive to drive.*
>
> *F, SH, D (decreased activity)*

Some residents had a more positive view, and indeed owned a car, mainly because of the option to purchase a dedicated car parking space in or close to the building in which they lived. Although a significant cost, this was seen as attractive, even if it was not used that often, and affordable relative to other costs and income, largely for those in the intermediate housing sector. Car ownership was reported less by those in the social housing sector, who tended to rely on friends and taxis for access. Other transport options influenced the decision whether to own a car or not, which was expressed as a weighing-up of options, for example the cost of car parking versus the cost of train travel at weekends:

> *From this side of London you've got access to quite a few different sort of bigger places and the train fare [sic] sometimes are just ridiculously high for a spur-of-the-moment kind of thing that you want to do.*
>
> *F, IH (intermediate housing), D*

Cars were rarely used during the week if a participant was commuting for work into London, as public transport was a more viable option. Good public transport infrastructure was frequently cited as a key reason for not needing a car:

> *There's no point having a car.*
>
> *F, SH, D*

Furthermore, the view was expressed that it would be different if public transport infrastructure was not available:

> *If I lived somewhere with minimal transport . . . I'd get a car.*
>
> *F, SH, D*

Other than differences between housing sectors (e.g. less likely to own a car in the social housing sector), car ownership did not vary particularly between the activity change groups (increase, no change, decrease).

Feeling safer

A consistently reported change across all groups since moving was an improved perception of safety to be out at night. This was largely a result of improved lighting and the presence of other people, and led to more reported walking at night both for leisure and to get to destinations than was reported in their old neighbourhood:

> *It's going to be 9:30 or 10, so there's still activity and there's lighting, whereas where I lived before, that whole side I had to walk it was a very quiet road, there's no lighting there, so that makes a difference for me . . . you can even walk at 11 p.m. There's always activity . . .*
>
> *F, SH, I (increased activity)*

This was most frequently reported by women in relation to personal safety and removed what was a recognised barrier to activity:

> *. . . the perception is it's safer and then when you actually see like the crime stats and things it is safer, so that kind of makes you think, right, I'll go out for a run, I'll be fine.*
>
> *F, IH, D*

This was also reported in relation to the general design, which had wider open spaces to increase visibility:

> *I've never felt unsafe . . . feel more unsafe in areas where there are more cars because there's more potential for me not to see something coming up on me, whereas here . . . you can tell someone's intention when they're on foot, so in that respect, I feel safer here.*
>
> *F, IH, D*

Therefore, the combination of good lighting, other people being around and space to observe those around were key to the improved perceptions of safety at night.

Aesthetics

Participants reported the advantages of wider pavements and diverse buildings, with the combination of more green spaces amid the built spaces seen as a positive compared with previous neighbourhoods. Noise, although not traditionally included as an aesthetic feature, is included here as it was mentioned by many participants in several contexts both positive and negative.

A reduction in traffic-related noise was consistently reported as a positive aspect of the residents' new environment; however, noise within East Village was also reported as a potential negative. This was dependent to some extent on familial status, with residents without children commenting on children's noise from playing outside whereas those with children commented on loud parties/groups sometimes in the communal areas, such as the barbecue areas. This affected the use of space and the choice of spaces to go to (e.g. to avoid identified 'play spaces' or those that attract crowds, such as barbecue spaces). This led to clear patterns in use of space with residents matching their needs and led, to some extent, to spatial segregation. However, the large amount of space and diversity of options meant that this did not necessarily restrict the use of outdoor space although to some extent it limited social interaction between some groups:

> *I don't use the central courtyard at all. I just find that really awkward. It's a nice space to have but . . . it doesn't feel very adult to me, so there's lots of different sized families and people that live here and the kids use that space quite a lot, but it doesn't really feel very grown-up to me, so I just don't bother with it.*
>
> *M (male), IH, D*

Destination features

Use of sports facilities in East village

Despite awareness and positive views about living in a neighbourhood with sporting facilities and the status of being connected to the Olympics, very few participants reported using the facilities. The most consistent reason was price:

> *The gym is too expensive . . . the swimming pool . . . no I haven't used that . . . due to expenses again.*
>
> *F, SH, I*

There was awareness of potential subsidies and possible use in the future when eligible:

> *I feel that when I become a pensioner I will take off whatever they do there . . .*
>
> *F, IH, I*

Others reported limited interest, as some participants did not feel that the sports facilities were appropriate for them as they had little experience or interest in sport.

There were a small number of examples of participants taking up new sports activities in the village, mainly those who had previous experience of running or playing sport. Social media was a key way to communicate for group-based activities:

> *By Facebook [Facebook, Inc., Menlo Park, CA, USA] so there's lots of Facebook groups for East Village, different things, all sorts of things, umm, football being one of them, so yes, I play with my neighbour, B, and he's a teacher at the school so he was like the initial contact and then I met other people through the football . . .*
>
> *M, IH, NC (no change)*

Flexible public transport options

Public transport was a dominant component of most conversations owing to the multiple options available to residents of East Village. This affected their active travel decisions and behaviour but did not necessarily have an impact on increased active travel compared with where they used to live. The active component was largely unchanged:

> *. . . same distance, 10-minute walk . . . but it's just different routes.*
>
> *F, SH, D*

In some instances, public transport options actually reduced travel-related physical activity since moving to East Village, either through direct factors (e.g. participant moved there to be nearer work) or because transport connections were improved compared with their previous residence. Participants generally felt that wayfinding was relatively easy within East Village and took advantage of the variable transport options when planning their journey. They invested considerably in minimising journey times by having highly planned use of public transport routes, which included minimising the amount of walking as part of the journey. This was related more to time saving than to avoid walking, but had probably affected the length of the walking component of regular journeys (e.g. to work) since moving to East Village. Participants also selected travel options to avoid certain places, particularly Westfield Shopping Centre, which was seen as a busy and uninviting through-route unless participants were actually shopping. Options included using the Docklands Light Railway or taking the bus:

> *But I use the bus a bit more now because it's so convenient because it's literally a 5- or 10-minute walk to the bus stop and it drops me off pretty much right outside work . . . but also it's a short walk through Stratford, through Westfield, to get to the Central Line and then it's two stops on the Central Line. I don't*

like going that way because it feels like I'm walking ages and I hate going through shopping centres in the mornings, but yes, I can get the bus, so it's more tempting if I don't want to cycle.

F, IH, NC

Participants also valued through-routes where changes were not required or that were less busy, which was often the case for bus routes:

I know, because before, when I was travelling to . . . there was no direct route, really. You'd have to change and . . . the one thing about public transport [here] is I love it, I love a smooth journey, or I just sit there and I go A to B, which is why the bus journey is so attractive because it just/it's just there, and it just takes you right to the station. You don't have to get off and change for a second one or anything like that. So I think that's probably why I use it a bit more than I did.

F, IH, NC

Indeed, public transport was often a factor in the decision to move and stay in the East Village:

. . . the transport links are better from here, so that's kind of the appeal for staying here, I kind of think, you know, why would I want to move somewhere that's going to be harder to get to work.

M, IH, NC

Green space

Many residents appeared to consider walking or cycling in the local area in a more positive light than they did in their previous area, but more in relation to leisure activity. Some residents found walking or cycling an enjoyable activity regardless of their location, but the addition of a more pleasant green environment influenced both their journey decisions and their decision to move to East Village:

. . . you know, we're not near any main roads, tick, that's really nice. We've got the park, tick . . .

M, IH, I

That park out there, as well, it's quite small now . . . half of it has now been built on, but the other half is kind of a little/I call it a glen-style with trees wrapping around a kind of a very large grassy area and there's lots of just trees and convenient seating and that on the walk up, so those are very heavily used.

F, IH, NC

Better access to resources: shopping, health care and destinations

Many participants commented on the resources being more easily accessible than in their previous neighbourhood, that is they were close by with minimal travel required. It was perceived to be easy to get to local resources such as general practice surgeries and dental practices as well as local shops and cafés:

Yes. If you wanted to go for a walk you could/2 minutes out there and you're walking around the Olympic Park. If you want to go to shop, 5 minutes and you're in Westfield. It's/you can have whatever you want here. As much . . . as you want, so it's quite/it's well placed.

F, IH, NC

However, some residents articulated that they felt that East Village was less diverse in relation to destinations and places to go and was less centrally located to link to other neighbourhoods, which might prompt less planned or structured physical activity:

Not small shops . . . No. There's just/around here there's no sweet shops sort of thing.

F, SH, D

> *But we don't walk into town as much as we used to, only because it's not quite a central location as [before] . . . we might have walked into other neighbourhoods . . . We tend to go to the park for a stroll, umm, but otherwise not really I'll just be on the couch for a couple of hours, umm, whereas before we might have gone for a stroll a bit more I think.*
>
> *M, IH, D*

Positive perceptions not enough

Although, as highlighted above, the residents' perceptions of environmental features in the East Village were generally very positive, these positive perceptions were not in themselves enough to promote increased physical activity overall. Other factors mediated the relationship between the environment and the participants' behaviour. Some of these were individual factors related to motivation to be active for health reasons and a sense of being active to take responsibility for your own health:

> *. . . if I have to lose weight, let me discipline myself and walk up and down [I don't need a gym].*
>
> *F, SH, I*

The environment was a prompt for participants with a lot of previous activity experience to reintroduce old practised behaviours, such as re-joining a gym or taking up running again. A change in circumstances also superseded environmental influences, for example new work patterns (e.g. working long hours), change in capacity (e.g. because of surgery) or age, which was a reported barrier to taking up new activities owing to high levels of perceived risk, even within a supportive environment:

> *No, not going to ride a bicycle, not at my age now. Even if I did it would be in a very safe place. I'm not Lara Croft!*
>
> *F, IH, I*

Early stages of neighbourhood development

It was also acknowledged by participants that East Village was still developing and did not feel as vibrant as more established areas:

> *I think it's because we . . . could kind of walk down . . . which was kind of cool, a bit snazzy and then make our way back through the back streets or something, whereas here it's not quite the same, like you haven't quite got the same vibes.*
>
> *F, IH, I*

However, it was also noted that the East Village was changing and evolving into a more interesting space as new facilities were introduced, albeit they were relatively limited:

> *. . . it feels like its grown into itself so there's much more going on, like you said, the café's downstairs, there's some restaurants . . .*
>
> *F, SH, I*

Part of this evolution that was particularly slow was the social development between residents within the village. Many residents reported having positive experiences with visitors to East Village and maintaining contact with their old neighbourhood by visiting or by using social media, but there were few examples of social interactions between residents apart from among children within families and for structured activities, for example playing football. Residents were aware of group activities but did not report participation in activity. There was, however, participation in more static social events, such as when football was screened outside or in the barbecue area.

The level of social connection was to some extent influenced by a sense of connectedness to East Village. Some were less connected as a result of strong ties to their previous neighbourhood; this was particularly true for younger adults for whom the move was more of a family decision than their own decision.

In most cases this was the result not necessarily of a negative view of the new neighbourhood but of a specific connection to their old neighbourhood. Others had little connection to their old neighbourhood and were keen to explore their new neighbourhood, extending their range and sense of place as time went on. They were keen to invest in their new neighbourhood environment marked by, for example, walking and/or testing new neighbourhoods, appreciating new activities and shops, and having a clear sense of pride in where they lived.

Discussion

The spatial narrative interviews show that the majority of residents felt that East Village had many positive elements and, in many cases, was an improvement on their previous neighbourhood. These perceptions generally reflected a positive view of their move and some were directly related to their travel patterns and activity (e.g. availability of facilities, green space, perceived safety owing to lighting of walkways), whereas others potentially had an indirect effect (e.g. nice buildings to view, perceptions of space).

Consistent with the findings from the quantitative data reported in Ram *et al.*,[64] those living in social housing particularly emphasised the positive environment of their new neighbourhood relative to their old neighbourhood. This was not necessarily because they found the new environment any more positive than did other groups but rather because they had more negative perceptions of the built environment in their old neighbourhood than the other housing sectors. Safety was a particularly consistent positive change, particularly feeling safe to be out at night, and is consistent with the shift in crime perceptions reported in the survey data (see *Chapter 6*).

The improvement in perceived personal safety is an important finding as it is a consistent correlate of physical activity, particularly for women,[250] and demonstrates that effective design such as good-quality lighting can extend the time period available for activity (i.e. to include dark hours). Improved lighting may also prompt more people to be out, which in turn was cited as a reason for increased confidence to walk at night.

One of the factors normally associated with increased opportunities to be active is a good public transport system. However, the relatively sophisticated options in East Village may in fact have diluted this effect, as participants were able to effectively minimise walking time by using a range of options. Although cycle lanes were acknowledged, there was little evidence in these interviews of their regular use for commuting; they were used more for leisure than for routine physical activity. The high level of accessibility of destinations is similarly a recognised determinant of increased activity,[94,250] and this was viewed as an advantage by residents. Although distances to destinations were short, for example there were facilities such as general practice surgeries, dental care and shops on site, this may have limited the need for sustained walking. These observations may help to explain the very limited change in active travel based on the GPS and accelerometry data highlighted in *Chapter 5*. This in turn may have affected the potential change in overall activity, as transport-related activity is such a strong component of activity profiles.[241] These qualitative findings are also consistent with objective indicators of the environment, as reported in *Chapter 4*, with the East Village demonstrating high levels of walkability, green space and access to destinations.

The limited potential for change in the transport-related activity highlighted above emphasises the important role that leisure activity plays in physical activity levels. Interviews supported the view that many elements in East Village stimulated physical activity, but these examples were often infrequent and 'one-off' events rather than routine activities that would have an impact on daily physical activity levels. However, these were highly valued by residents, and it is possible that with time these examples would grow into more habitual activity. On the other hand, it should be acknowledged that for many these were new or different behaviours compared with their previous experience (e.g. going for a bike ride or

longer walks, taking part in exercise groups outside), so environmental stimulus alone will have only limited impact. Social–ecological frameworks acknowledge that change at individual, social and environmental levels is required to promote and sustain significant change. This also explains to some extent why significantly improved perceptions of the environment do not necessarily have an impact on physical activity behaviour. Other factors (e.g. personal capacity, motivation) as well as social and familial factors mediate the relationship between the environment and physical activity. There is less evidence that these have changed since moving to the East Village, particularly social relations between residents within East Village. Many social activities are still dependent on social activities outside the village. There is evidence that this 'social infrastructure' is developing as the built environment develops, but the effect is subtle and takes time. It relies on places to meet, share and engage beyond the provision of green space or large shopping centres. The provision of smaller shops and cafes is an example of how the environment is becoming more diversified and one successful social space does attract residents (the barbecue area and screening of events). As acknowledged in other similar studies,[94] changes can take some time to develop, particularly if they are not a result of shifts to routine behaviour via transport activity. These qualitative data emphasise how a newly built environment takes time to evolve; this is reflected in residents' reported early interactions with the environment. This is described both practically in terms of knowing where to go to fulfil daily life activities, but also emotionally in terms of where to feel comfortable in terms of a sense of neighbourhood. This process can be accelerated by environmental shifts; as facilities and businesses become established, clusters to represent known and comfortable destinations for residents emerge. Although the sporting facilities are generally seen as an asset to the neighbourhood, price remains a barrier to participation.

The strengths of these findings include the use of participants' own spatial data both to select a group of participants who have changed differently from baseline to follow up in the ENABLE London study and to provide a basis for participants to describe their use of the environment and their perceptions of it. Although reports were retrospective in relation to participants' previous environments, having examples of traces both before and after from the GPS data provided an important memory prompt, as well as a dynamic basis for discussion of change. These qualitative one-to-one interviews were also able to capture temporal shifts and how these may oscillate over time. This provides an important complement to the objective measures that, although longitudinal, can provide only a snapshot at baseline and follow-up. This is particularly important because participants' spatial patterns are highly variable, which makes it difficult to capture them with short-term measures. Participants were also able to focus on the factors most salient to them and explain how they interact to influence behaviour, which is challenging with quantitative data even with sophisticated analyses.

Limitations include the relatively unusual transport structure within London, which provides residents with transport options and a decision-making structure that may not relate to other, less urban or smaller, areas. Although the use of participant data and information at baseline allowed sampling to be targeted to reflect a range of participants, those who were interviewed were relatively young compared with both the wider sample and the population, so these findings may not necessarily translate to the perceptions of older adults. Participants were also sampled based on travel patterns, which may not necessarily reflect overall activity for some individuals.

Conclusions

East Village is seen as a very attractive place to live, with the majority of participants expressing more positive perceptions of their built environment than of their previous neighbourhoods. It was also seen as a place that included many environmental elements, to encourage increased activity. However, these positive perceptions in themselves were not enough to prompt use of the environment to the extent that it increased physical activity overall. It did stimulate use of the space for leisure, but any change was offset to some extent by the limited options available to increase transport-related activity.

This was in part explained by the sophisticated use of an extensive public transport network close to East Village. It is clear that the built environmental structure of East Village is still evolving, with smaller facilities, shops and cafes opening that will continue to diversify and build the neighbourhood. This alongside a more developed social infrastructure may have an impact on physical activity in the long term, encouraging residents to make use of their environment more frequently for activity and leisure.

Chapter 9 Discussion

Introduction

Low physical activity is widespread and poses a serious public health challenge both in the UK and worldwide.[251] The need to increase population levels of physical activity is recognised in current health policy recommendations.[5,252] However, interventions to increase physical activity levels, particularly community-wide interventions, have shown limited effects that are poorly maintained in the longer term.[29] There has been increasing interest in whether or not the built environment, especially in urban settings, might be a key constraint that limits opportunities for physical activity.[31] However, there is very limited high-quality experimental evidence examining the influence of change in the built environment on physical activity.[30,31] The ENABLE London project was established to address this issue, by providing evidence from the investigation of a natural experiment examining whether or not a sizeable change in the built environment can increase physical activity levels, as well as indicators of both physical and mental health, in the general population. This question has important public health relevance as small shifts in population levels of physical activity, in addition to other markers of health, can have an appreciable impact on health-related outcomes.[253]

Principal findings

The East Village development, a neighbourhood repurposed in accordance with active design principles, resulted in sizeable improvements in objective measures of the built environment and neighbourhood perceptions of the local built environment among those who moved there compared with those who did not. However, after 2 years, moving to East Village did not have any consistent beneficial effects on objectively measured physical activity, adiposity or other health-related outcomes of public health importance. Although modest reductions in car travel and increased use of public transport were observed among those who moved to East Village, these did not materialise in demonstrable change in active modes of travel (i.e. time spent walking or cycling). These findings suggest that the built environment is insufficient on its own to change physical activity behaviour. More evidence from similar longitudinal studies is needed to confirm these findings. However, given the difficulties and costs of this type of study, which relies on urban regeneration, we may need to think of innovative approaches to evaluate the effect of housing and urban change developments on health, to inform future evidence-based housing policy.

Principal contributions and implications of the study

Explaining the effects of the intervention

Understanding the mechanism through which the built environment might influence health behaviour is not straightforward and may well be multifaceted.[96] Reasons for the lack of clear effects of the East Village development, the 'intervention', on the physical activity-related behaviour of residents remain to be fully understood,[33] especially when findings from cross-sectional studies are less equivocal.[93] One potential explanation is that those seeking to move are inextricably different from those who do not. The ENABLE London study sought to minimise this bias by recruiting a cohort of individuals seeking to move to East Village, which we believe, in the absence of randomisation, offers the best possible study design. It is also possible that the magnitude of change in the built environment was insufficient to induce a major change in physical activity. However, the East Village development showed marked changes in objective GIS-derived markers of the built environment and sizeable improvements in neighbourhood perceptions (particularly in perceptions of crime and quality) among residents moving

to the area compared with those who did not move or moved elsewhere. So why did the change in the built environment not result in a bigger change? This report ventures a number of explanations, including whether exposure to the environment was long enough or sufficient enough to induce the change expected; the environment was incomplete when the first social housing residents moved in and was compromised by further high-rise development and loss of green space more latterly.[218] In the absence of more discernible effects on health and behaviour, it is difficult to establish clearer explanations for the lack of more definitive findings. However, it appears that the built environment alone is insufficient to induce the change in health behaviour expected by passive means and that more interactive strategies, perhaps in conducive environments such as East Village, are needed (i.e. perhaps higher-agency programmes combined with low-agency environments are needed to induce change). However, although high-agency population interventions are often used, particularly by governments to improve diet and reduce obesity, they are often ineffective[254] with time constraints and low levels of motivation often being cited as reasons for poor uptake.[255] Moreover, high-agency interventions that require more effort from the individual may reinforce or even worsen socioeconomic inequalities in health.[254] Hence, low-agency interventions that require less investment from the individual may be more effective, having a small effect in greater numbers and hence may be more equitable by having greater reach.[254] In the context of East Village, greater agency could be achieved through greater awareness among the residents of the activity-inducing features and facilities that exist (such as walkways, cycleways and sporting venues) and fostering the belief, particularly among social tenants, that these are available to all. However, the premise of this study was to examine the effect of the built environment per se, without these additional 'nudges' to promote use.[256]

Generalising the effects of the intervention

In terms of the representativeness of the ENABLE London cohort, we compared our physical activity data at baseline to a nationally representative study, the Health Survey for England,[257] that used a similar methodology: the same waist-worn accelerometer (ActiGraph) worn for an equivalent wear time (1 week). Adults aged 16–34 years from this study recorded 40 minutes per day in MVPA, of which, on average, 15 minutes was in 10-minute bouts. Our baseline data suggest comparable levels of activity among those of a similar age in the social sector with 47 minutes of daily MVPA and 7 minutes in bouts (with an IQR between 1 and 15 minutes), but higher levels among those in the intermediate and market-rent sectors with 65 minutes of MVPA and > 20 minutes recorded in bouts. Although this suggests differences in baseline physical activity levels across the housing sectors in the ENABLE London cohort, there was no evidence of a trend across other social markers (i.e. income groups) in the Health Survey for England study. Moreover, the greater change in physical activity associated with moving to East Village in the intermediate and market-rent tenured groups compared with those in social housing, does not suggest that these higher levels (albeit not significantly higher) limited scope for change (i.e. participants from these non-social tenured groups had reached the capacity for further increases). In terms of geographic patterns in physical activity, reanalysis of the Health Survey for England[7] data did not suggest that self-reported higher levels of physical activity in London were unduly higher or lower than other government office regions.[258] Hence, we believe that null findings from the ENABLE London study do not reflect bias within our cohort and are transferable beyond our study population. However, it is acknowledged that a cohort of 'movers' seeking to move to East Village, an active permissible space being built on active design principles, were targeted for the study and their activity patterns may differ from the population at large. Hence, this may have some implications for the generalisability of the findings.

In terms of specific features of the East Village development that could have influenced health and well-being (such as the use of pathways, cycle paths, links to public transport, open spaces and leisure facilities) are (or could be) features of many built environment developments. Hence, we believe that findings from this study have substantial potential for wider generalisability to other urban areas. An ultimate goal of the project was to identify evidence-based design features of the built environment

that encourage physical activity and improve health behaviours. It was hoped that the identification of these environmental features would provide architects, urban designers and planners with evidence-based urban design elements, which are required for future developments.

We hope that findings from the ENABLE London study will be generalisable to other urban residential housing developments, especially given the urgent need for higher-density housing, and will help inform evidence-based urban planning in future.

Methodological investigations and development

We believe that the ENABLE London study design that we have developed offers a robust test of the effect of the built environment on physical activity and health behaviour, in the absence of randomisation. We did explore carrying out randomisation of accommodation with Triathlon Homes, a partner organisation of housing associations, which manages social and intermediate homes in East Village, but unfortunately this was not feasible. Hence, the approach used offers the next-best alternative. The richness of the data recorded, although making participation and data collection more onerous, provided an excellent opportunity for novel exploration. The development of an automated method of recording travel mode journeys from combined accelerometry and GPS data allowed change in active forms of travel to be examined in an objective automated way, which would have been prohibitively lengthy using previous manual approaches.[48,49] The tool developed (outlined in *Chapter 5*) has been validated in the cohort (as well as in a separate study) and although it showed little change in active forms of travel (i.e. walking and cycling), consistent with no overall change in physical activity levels (see *Chapter 3*), it showed modest reductions in car travel and an increased use of public transport (i.e. underground), which was associated with moving to East Village. These methods have been published and made available for use by the wider scientific community, offering an ongoing legacy from the work.

Engagement with patient and public involvement/stakeholders

The ENABLE London study was developed in partnership with a network of both local and regional stakeholders identified through our collaborator links to agencies, which were involved with the design, planning and management of large-scale accommodation developments. Locally, these included local authorities (particularly Newham) and a number of housing associations, in particular the East Thames Group and Triathlon Homes (which continue to be responsible for social and intermediate tenured housing in East Village). Open meetings held by the East Thames Group and Triathlon Homes were attended by the investigators at an early stage of the project, to directly interface with those contemplating moving to East Village, to establish the drivers and reasons for considering moving to East Village, and to ensure that these were fully captured in the forms of assessment. Moreover, qualitative work was also convened early on in the project to gauge experiences among those who were the very first to move to East Village, so that follow-up examinations could be adapted to ensure that all relevant areas were covered, and that assessments and participation remained engaging and enjoyable, and to ensure the continued significance and potential generalisability of the work. Another key aspect of engagement/stakeholder involvement was attendance and presentation at national and international conferences and special stakeholder workshops, particularly those convened by the Town and Country Planning Association at an early stage of the project, to encourage further stakeholder participation and to share experiences with other researchers carrying out similar work; this provided the opportunity for ENABLE London study methods to be refined and optimised. Similarly, publications to date, particularly those describing study methods and baseline data, also provided opportunities for further dissemination and potential input from those working within the field. The investigators continue to be in contact with representatives of the Town and Country Planning Association, Public Health England and the London Borough of Newham not only to disseminate findings from the ENABLE London study but, more importantly, to inform the future direction of research in this area, with the goal of providing stakeholders, architects and planners with the evidence base needed to inform future housing developments.

Challenges, strengths and limitations of the study

Challenges of the study

The ENABLE London study provided a unique opportunity to observe a 'natural experiment' to assess the impact of a rapidly changing built environment, specifically designed to encourage walking and cycling, on the physical activity patterns of residents. Natural experiments are associated with a number of challenges that are often out of the control of the researchers. Our original plan, as specified in our bid for funding, was to carry out the baseline recruitment between January 2013 and mid-2014 and then to follow up participants after 1 year, between January 2014 and mid-2015. However, there were marked delays in the release of East Village accommodation, which resulted in a prolonged period of recruitment from January 2013 to January 2016. In addition, the delayed opening of East Village facilities (a crucial element of the East Village environment and the natural experiment under evaluation) led to a postponement of the follow-up assessment from 1 year to 2 years. The scientific case for delayed follow-up was strong in that (1) East Village was not fully open for use in 2014 when first follow-up was initially envisaged and (2) previous studies have suggested that it takes 2 years as opposed to 1 year for habitual levels of physical activity to change in response to a changed built environment.[44] The scientific rationale for 2-year follow-up was approved by our Trial Steering Group. As a result, the timing of the follow-up examination (originally envisaged to take place between January 2014 and mid-2015) began in February 2015 and was completed in October 2017. We remained adaptive to these challenges throughout the study by modifying the working hours of field workers in response to demand (particularly making use of part-time as opposed to full-time appointments) to ensure that the research funding that was awarded covered the extended period of fieldwork. However, the prolonged period of fieldwork inevitably resulted in difficulties in consistency of the exposure to the built environment, which, as outlined above, was underdeveloped at first follow-up, becoming fully open and then more latterly overdeveloped from what was initially envisaged (see *Limitations of the study*). Moreover, the high levels of rental tenure in East Village resulted in a more mobile population, and many of the intermediate and market-rent occupants who took part in the study have since moved away from the area.

Strengths of the study

The building of East Village provided an important novel opportunity to evaluate a 'natural experiment' based on the major and focused change of an inner-city urban built environment that has been specifically designed to encourage walking, cycling and healthy living. It is also unique because the study included residents from widely differing socioeconomic backgrounds. Although many developments of this scale are under way or are being planned in cities globally, few have been (or are being) evaluated and most are less easily evaluated given that the timescale of their development is much longer than in the case presented by East Village. The rapid occupancy of this development was a major strength, providing the opportunity for pre and post assessment and to compare 2-year change in health outcomes among those who did and did not move to East Village. The different housing tenures within East Village also allowed for the evaluation of socioeconomic position as an effect modifier, as the impact of the built environment may vary by socioeconomic position. The focus on increasing levels of accessible and low-cost forms of physical activity remains particularly relevant to individuals and households of lower socioeconomic status and has the potential to inform efforts to reduce health inequalities.[259] This allowed us to examine whether or not the built environment favourably influenced higher levels of physical activity (particularly walking and cycling), as well as reducing time in sedentary activities, particularly among low-income groups with fewer opportunities for recreational activities.[259] Moreover, the co-location of this diverse population of differing housing tenures to one community also constituted a social experiment, providing opportunities for residents to observe and learn from the behaviour of others.[260]

Another key strength is that the study sought to recruit a cohort who were seeking to move, half of whom succeeded and half of whom did not, which avoided potential biases in health behaviour. In the absence of randomisation, we believe that this study design offers the next-best alternative, providing less biased

and more robust evidence about the potential effect of the built environment on health-related behaviours and outcomes. Following the same individuals before and after any move to East Village also offers statistical efficiencies in that individuals act as their own controls, which eliminates confounding factors that do not change within subject.[261,262] Moreover, the consistency of effects using 1 or 4 days of objectively measured physical activity allays fears about potential selection effects associated with using fewer days of recording, which were needed to maximise the number of study participants, particularly among the harder-to-reach social housing sector. The use of accurate objective assessment of physical activity is another strength, including assessments of MVPA that underpin current physical activity recommendations;[4] this allows the potential public health importance of the findings to be gauged. However, effects on MVPA were small, suggesting that the change in the built environment had limited impact in achieving current physical activity recommendations, which focus on higher levels of activity.[4] Objective assessment of physical activity assessment reduces measurement error and potential biases arising from self-reported levels of physical activity,[88] which could be artefactually associated with moving to a new environment being advocated for healthy active living. Furthermore, we have recently published a paper comparing the effect of a successful pedometer-based walking intervention on change in physical activity observed from accelerometry and IPAQ forms of assessment, and have shown that the change in physical activity was estimated with far less precision compared with the hip-worn accelerometry form of assessment.[263] Hence, use of the IPAQ data would lead to greater uncertainty about the findings, which already show no clear evidence of effect. Similarly, objective measures of adiposity using validated measures of bioimpedance minimise measurement error and limit any potential biases in ascertainment, particularly among a multiethnic population.[264,265] The ability to examine different socioeconomic groups allows social inequalities in effects and potential determinants to be examined.[266] Although there was the suggestion that change in physical activity was greater in the intermediate sector than in the social housing and market-rent groups, there were no clear differences observed by housing sector, emphasising that the study was underpowered to formally examine impacts on health inequalities.

Limitations of the study

A key limitation was that the study was powered to detect a 750-step difference.[61] Hence, the study was underpowered to show that the change in steps observed associated with moving to East Village compared with the control group was statistically significant overall (i.e. 154 steps, 95% CI −231 to 539), let alone in housing tenure subgroups with fewer participants. Effects on MVPA associated with moving to East Village (particularly in ≥ 10 bouts, commensurate with current UK physical activity guidelines)[4] were small and uncertain (i.e. effect estimates were associated with wide CIs). Limitations in sample size were a result of the modest participation rates (50–60%) and unforeseen restrictions on recruitment, particularly among the market-rent sector.[61] Moreover, the staged recruitment in which those in the social sector were moved in first when East Village was not fully completed, may have resulted in partial exposure to the physical activity promoting environment and before residential density had reached capacity, which may have limited the full impact of the exposure.[61] This was partly a reason for follow-up after 2 years rather than 1 year, but also because previous work has suggested that longer durations are needed for habitual health behaviours to evolve and to avoid early 'honeymoon' effects[44,267–269] or, conversely, for residents to become fully familiar and make optimal use of their residential area.[148] The RESIDE study found stronger differences over time, as suburbs evolved and new facilities were built and habits became more established.[95] Further follow-up could plausibly demonstrate beneficial effects but given the mobility of the cohort and the fact that the study is underpowered these are unlikely to yield statistically significant findings. Moreover, East Village is evolving and the building of high-rise accommodation (> 30 storeys) among the existing 10- to 12-storey accommodation, and subsequent loss of green space, may dampen exposure effects even further.[218]

Information on social environmental factors, including qualitative research exploring the lived experience of residents, may help to explain why residents of this new area did not respond to an environment designed to be health promoting. It is plausible that the facilities provided did not meet the needs of the new residents and/or they did not feel welcome to use those facilities, especially

social housing participants.[233] This requires further exploration. However, another reason why effects were not more evident might be that London is largely a 'green city', especially in relation to other capital cities,[270] limiting the opportunities to detect change if controls moved to an equally good space. However, the effect was in fact marginally strengthened when comparing East Village with controls who moved elsewhere and the difference was reduced when comparing East Village with controls who remained at their baseline address, suggesting that this is not the case. There was also no effect of moving to East Village on adiposity levels, and no effect on mental health and well-being outcomes of public health importance.

Another limitation was the adult focus of the study, as East Village did not attract as many families as anticipated, leading to a limited number of children being recruited to participate in the study. This was also evidenced by the Chobham Academy, originally designated to educate children moving to East Village, having to increase the catchment area to fill its pupil capacity. This was an unforeseen circumstance, out of the control of the researchers, which resulted in the study being underpowered to determine any change in physical activity and health behaviours associated with moving to East Village among this age group. Hence, this limits the generalisability of the findings, particularly to younger age groups.

Implications for future research

Although it remains plausible that the built environment alters physical activity patterns and other health behaviours, this study suggests that the effects may be small, particularly, as in this case, when people relocate into new high-density neighbourhoods. There are many discussions globally about the health impacts of high-density urban living, particularly high rise, and there is an urgent need to mitigate potentially adverse consequences.[26] However, this does not mean that a small effect across a whole population is unimportant. In contrast to other community-wide interventions, which have shown limited effects on physical activity,[29] change in the built environment potentially has greater reach. Even though there were modest effects on MVPA, potentially a 400 step per day change (observed in the intermediate group) across the whole population could have appreciable effects on health outcomes at a population level, potentially reducing all-cause mortality by 2% (95% CI 1% to 4%).[271] However, further evidence is required, particularly about the factors that resulted in social housing residents who relocated actually decreasing their level of physical activity. Such studies would have to be large in scale, larger than the ENABLE London study, to demonstrate change. As availability and affordability of housing is a pressing concern, particularly in major conurbations such as London, and the environments in which we live and the accompanying social context have been shown to be related to physical activity levels (including higher levels of physical activity),[104,272] more studies evaluating the effect of large-scale housing redevelopment and/or new development programmes are needed to inform the debate about future housing policy. These studies should be diverse in nature to encompass high-density as well as low-density housing. Moreover, suitability and attractiveness of these housing types to different populations (young and old, different tenures and income groups) should be considered to improve the generalisability of potential findings, whether these be favourable or otherwise.

Although there is a strong scientific case for such large-scale studies, challenges of funding, especially in the current economic climate, will limit opportunities. Hence, novel approaches using simulation studies or alternative low-cost forms of population surveillance may be needed to make such large-scale studies viable.

Conclusions

There is a need to shift from the paradigm of cross-sectional studies to stronger research longitudinal designs that make use of large-scale residential relocation opportunities. Natural experiments that make use of circumstances in which people relocate to a new built environment are ideal.[41,83]

However, despite the growing need for housing, especially in major conurbations such as London,[273] opportunities for such studies are limited. Challenges include the need to identify and engage with proposed developments from an early stage, the need to obtain access to those planning to move well before any move occurs, the need to recruit sufficient participants, the unpredictability of creating environmental interventions as planned, and the need for flexible funding to adapt to unforeseen delays given the researchers lack of control over any potential build. Only by assimilating evidence from such studies conducted in different types of neighbourhood, which employ common methodologies that can be directly combined, can the effect of the built environment on physical activity be fully elucidated and understood to inform the planning and provision of housing for optimal health.

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Christopher G Owen (https://orcid.org/0000-0003-1135-5977) (Professor of Epidemiology, St George's, University of London) was the principal investigator leading on the design and execution of the study, oversaw all study analyses and publications and led the preparation of the final report.

Elizabeth S Limb (https://orcid.org/0000-0003-0830-7376) and **Claire M Nightingale (https://orcid.org/0000-0002-4803-7617)** (Senior Research Fellow and Lecturer in Medical Statistics, St George's, University of London) were the primary statisticians for the ENABLE London study, responsible for data management, curation and analyses, leading on some and contributing to other publications emanating from the study, as well as the final report.

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Bina Ram (https://orcid.org/0000-0003-0023-1573) (Programme Manager and St George's, University of London, PhD student) was responsible for delivery of the ENABLE London study and data collection and management. She was also responsible for the mental health and well-being assessment in the ENABLE London cohort (with support from **Aparna Shankar**), leading on analyses and publications, and has contributed to publications emanating from the study and the final report.

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All authors contributed to the final report and approved the final version.

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Data-sharing statement

We welcome proposals for collaborative projects. For general data-sharing enquiries please contact the corresponding author.

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Appendix 1 Main questionnaire

SECTION A: HOUSEHOLD QUESTIONS

Fieldwork researcher name

Household ID

Firstly, how many people (including you) live here all together as members of this household?

1 □
2 □
3 □
4 □
5 □
6 □
More than 6 □

FW: Please specify how many members there are in the household _____

And how many members of the household are taking part in the study today? _____

What is your full name? First name: _____
Surname: _____

Sex

Male □
Female □

Your date of birth: DD MM YYYY

FW: If date of birth has been entered as 01 and month of birth as 07, please indicate if this is the correct date and month of birth

Date Yes □ No □
Month Yes □ No □

FW: So just to check, you are *(automatic calculation of age)* years old or will be this year? *If incorrect age shows, check DOB has been entered correctly.*

Now I would like to take a list of the names, sex, date of birth of all the people who live with you on most days in your house.

What is the name of the next person in your household? First name: _____
Surname: _____

Are they…

Male □
Female □

What is Person 2's date of birth? DD MM YYYY

FW: If date of birth has been entered as 01 and month of birth as 07, please indicate if this is the correct date and month of birth

Date Yes □ No □
Month Yes □ No □

FW check: Person 2 is (age) years old or will be this year? If incorrect, check dob is entered correctly.

How is Person 2 related to you?

Husband or wife □
Partner/same sex civil partner □
Son or daughter □
Step-child □
Brother or sister □
Step-brother or step-sister □
Mother or father □
Step-mother or step-father □
Guardian □
Grandchild □
Grandparent □
Relation-other □
Unrelated (including foster child) □

What is the name of the next person in your household? First name: Surname: _____ _____ _____

Are they… Male □ Female □

What is Person 3's date of birth? DD MM YYYY

FW: If date of birth has been entered as 01 and month of birth as 07, please indicate if this is the correct date and month of birth Date Yes □ No □ Month Yes □ No □

FW check: Person 3 is (age) years old or will be this year? If incorrect, check dob is entered correctly.

How is Person 3 related to you?

- Husband or wife □
- Partner/same sex civil partner □
- Son or daughter □
- Step-child □
- Brother or sister □
- Step-brother or step-sister □
- Mother or father □
- Step-mother or step-father □
- Guardian □
- Grandchild □
- Grandparent □
- Relation-other □
- Unrelated (including foster child) □

What is the name of the next person in your household? First name: _____ Surname: _____

Are they… Male □ Female □

What is Person 4's date of birth? DD MM YYYY

FW: If date of birth has been entered as 01 and month of birth as 07, please indicate if this is the correct date and month of birth Date Yes □ No □ Month Yes □ No □

FW check: Person 4 is (age) years old or will be this year? If incorrect, check dob is entered correctly.

How is Person 4 related to you?

- Husband or wife □
- Partner/same sex civil partner □
- Son or daughter □
- Step-child □
- Brother or sister □
- Step-brother or step-sister □
- Mother or father □
- Step-mother or step-father □
- Guardian □
- Grandchild □
- Grandparent □
- Relation-other □
- Unrelated (including foster child) □

What is the name of the next person in your household? First name: _____ Surname: _____

Are they… Male □ Female □

What is Person 5's date of birth? DD MM YYYY

FW: If date of birth has been entered as 01 and month of birth as 07, please indicate if this is the correct date and month of birth Date Yes □ No □ Month Yes □ No □

FW check: Person 5 is (age) years old or will be this year? If incorrect, check dob is entered correctly.

How is Person 5 related to you?

- Husband or wife □
- Partner/same sex civil partner □
- Son or daughter □
- Step-child □
- Brother or sister □
- Step-brother or step-sister □
- Mother or father □
- Step-mother or step-father □
- Guardian □
- Grandchild □
- Grandparent □
- Relation-other □
- Unrelated (including foster child) □

What is the name of the next person in your household? First name: _____ Surname:

Are they… Male □ Female □

What is Person 6's date of birth? DD MM YYYY

FW: If date of birth has been entered as 01 and month of birth as 07, please indicate if this is the correct date and month of birth Date Yes □ No □ Month Yes □ No □

FW check: Person 6 is (age) years old or will be this year? If incorrect, check dob is entered correctly.

How is Person 6 related to you?

- Husband or wife □
- Partner/same sex civil partner □
- Son or daughter □
- Step-child □
- Brother or sister □
- Step-brother or step-sister □
- Mother or father □
- Step-mother or step-father □
- Guardian □
- Grandchild □
- Grandparent □
- Relation-other □
- Unrelated (including foster child) □

FW: if there are ore household members, please take details on separate sheet of paper

FW: Does the main adult have children (including step, adopted or fostered?
Yes □
No □

Now a few questions about your home and where you live

How long have you lived at your current address?
Years _____
Months _____

What type of accommodation is this?
House of bungalow □
Flat, maisonette or apartment □

Is the house bungalow
Detached □
Semi-detached □
Terraced (including end terrace) □

Is the flat, maisonette or apartment…
In a purpose buit block of flats or tenement □
Part of a converted or shared house (inclduing bedsits) □
In a commercial building (for example, in an office building, hotel or over a shop) □
Other □

'Other', please specify (e.g. mobile home) _____

What floor do you live on? _____

Is there a lift?
Yes □
No □

Is the lift working?
Yes □
No □

Is this households accommodation self contained (this means that all rooms, including the kitchen, bathroom and toilet, are behind a door that only this housheold can use?
Yes □
No □

How many rooms are avalilable for use by this household (do not count bathrooms, toiets, halls, landings or rooms that can only be used for strage). Count all other rooms, for example, kitchens, living rooms, unitility rooms, bedrooms, studies, conservatories. If two rooms have been converted into one, count then as one room.

How many rooms are bedrooms? _____

Do you have at least one flight of stairs within your house/apartment?
Yes □
No □

Does your household own or rent this accommodation?
Rents with or withour housing benefit □
Lives here rent free □
Part owns and part rents (shared ownership) □
Owns with mortgage or loan □
Owns outright □
Other □

'Other': please specify _____

If you do not own the property, who is your landlord?

Housing asscoiation, housing co-operative, charitable trust, registred social landlord	□
Council (local authority)	□
Private landlord or letting agency	□
Employer of a household member	□
Relative or friend of a household member	□
Other	□

'Other': please specify _____

Does this household have a garden or communal space that you can use?	Yes □
	No □
Is this garden/communal space large enough and suitable for children to run around?	Yes □
	No □
In total, how many cars or vans are owned or available for use by members of this housheold? Include and company car(s) or van(s) available for private use.	_____
In total, how many motorbikes or mopeds are owned or available for use by members of this household?	None □
	1 □
	2 □
	3 □
	4 or more □
And finally, does your household own a dog?	Yes □
	No □

SECTION B: MAIN ADULT / PARTNER / OTHER ADULT QUESTIONNAIRE

The following questions are avout you, your neighbourhood, work and/or study, lifestyle/habits, and any phycial activities you may do. If there are any questions which you do not understand, please ask the researcher who will be happy to help. Please remember there are no right or wrong answers!

Your ethnicity

Please type in the name of the country in which you were born _____

What is your ethnic group?

White □
Mixed/mulitple ethnic groups □
Asian/British Asian □
Black/African/Caribbeab/Black Britsih □
Other ethnic group □

White

English/Welsh/Scottish/Northern Irish/British □
Irish □
Gypsy or Irish Traveller □
Any other WHITE background □

Please specify _____

Mixed/multiple ethnic groups

White and Black Caribbean □
White and Black African □
White and Asian □
Any other MIXED/MULTIPLE ethnic background □

Please specify _____

Asian/British Asian

Indian □
Pakistani □
Bangladeshi □
Chinese □
Any other ASIAN background □

Please specify _____

Black/African/Caribbean/Black Bristish

African □
Caribbean □
Any other BLACK/AFRICAN/CARIBBEAN background □

Please specify _____

Other ethnic group

Arab □
Any OTHER ethnic group □

Please specify _____

Your Qualifications

Which of these qualifications do you have. Tick all that apply
If your qualification is not listed, tick the box that contains its nearest equivalent. If you have qualifications gained outside the UK, tick the 'Foreign Qualifications' box and the nearest UK equivalent if known.

1-4 O Levels/CSEs/GCSEs (any grades), Entry Level, Foundation Diploma □
1-5 NVQ Level 1, Foundation GNVQ, Basic Skills □
5+ O Levels (passes)/CSEs (grade 1)/GCSEs (grades A*-C), School Certificate, 1 A Level/2-3 AS Levels/VCEs, Higher Diploma □
NVQ Level 2, Intermediate GNVQ, City and Guilds Craft, ONC, OND, BTEC National, RSA Advanced Diploma □
Apprenticeship □
2+ A Levels/VCEs, 4+ AS Levels, Higher School Certificate, Progression/Advanced Diploma □
NVQ Level 3, Advanced GNVQ, City and Guilds Advanced Craft, ONC, OND, BTEC Nattional, RSA Advanced Diploma □
Degree (for example BA, BSc), Higher degree (for example MA, PhD, PGCE) □

NVQ Level 4-5, HNC, HND, RSA Higher Diploma, BTEC Higher Level □
Professional qualifications (for example teaching, nursing, accountancy) □
Other vocational/work related qualifications □
Foreign qualifications □
No qualifications □

Employment

What is your current employment status? Tick all that apply.

In full-time employment (including full-time slef employed) □
In part-time employment (including part-time self employed) □
Seeking work □
Government Scheme (e.g. Helping Finding Work, Voluntary Schemes, Training Schemes, etc) □
Looking after home and family □
Retired □
Full-time student □
Part-time student □
Not working due to long term sickness or disability □
Other (including unpaid voluntary work) □

Please specify _____

What is your full and specific job title? (For example, Primary School Teacher, Car Mechanic, District Nurse, etc)

_____

Briefly describe what you do in your main job

_____

At your workplace, what is the main activity of your employer or business? For example, Primary Education, Repairing Cars, Contract Catering, Computer Servicing. If you are civil servant, type in 'Government'. If you are a local goverenment officer, type in 'Local Government' and give the name of your department within the local authority.

_____

Do you

Travel to a place of work/your place of study □
Mainly work/study at or from home □
No fixed work/study place □

What is the name and address of your workplace?
(question appears if employed)

_____

Postcode _____

What is the name and address if your place of study?
(question appears if studying)

_____

Postcode _____

Travelling to work and / or your place of study

Over the next seven days starting from tomorrow, on which days will you be travelling to work and/or your place of study?

Monday □
Tuesday □
Wednesday □
Thursday □
Friday □
Saturday □
Sunday □
None □

Usual Travel Times (Please enter times in either 12 hour or 24 hour format. If using 12 hour format, please specify am or pm)

What time do you **USUALLY** leave home to go to work/your place of study? (For example, please enter as 7am or 7:30am or 07:30) _____

What time do you **USUALLY** arrive at work/your place of study? (For example, enter as 8am, 8:00am or 08:00) _____

What time do you **USUALLY** leave your work/place of study? (For example, enter as 5pm or 5:00pm or 17:00) _____

What time do you **USUALLY** arrive home? (For example, enter as 6pm, 6:00pm, or 18:00) _____

Will these times be more or less the same over the next seven days when you travel to work/your place of study? Yes □ No □

On the days your travel time will differ, please indicate the times you will travel to work/your place of study on those days. (Please specify am or pm if using 12 hour format).

Monday:

What time will you leave home to go to work/your place of study? _____

What time will you arrive at work/your place of study? _____

What time will you leave work/your place of study? _____

What time will you arrive home? _____

Tuesday:

What time will you leave home to go to work/your place of study? _____

What time will you arrive at work/your place of study? _____

What time will you leave work/your place of study? _____

What time will you arrive home? _____

Wednesday:

What time will you leave home to go to work/your place of study? _____

What time will you arrive at work/your place of study? _____

What time will you leave work/your place of study? _____

What time will you arrive home? _____

Thursday:

What time will you leave home to go to work/your place of study? _____

What time will you arrive at work/your place of study? _____

What time will you leave work/your place of study? _____

What time will you arrive home? _____

Friday:

What time will you leave home to go to work/your place of study? _____

What time will you arrive at work/your place of study? _____

What time will you leave work/your place of study? _____

What time will you arrive home? _____

Saturday:

What time will you leave home to go to work/your place of study? _____

What time will you arrive at work/your place of study? _____

What time will you leave work/your place of study? _____

What time will you arrive home? _____

Sunday:

What time will you leave home to go to work/your place of study? _____

What time will you arrive at work/your place of study? _____

What time will you leave work/your place of study? _____

What time will you arrive home? _____

Will the next seven days be a **USUAL** working/study week? Yes □ No □

On the days that you will travel to work/your place of study in the week that starts tomorrow, how will you be travelling to and from work/your place of study? Tick all that apply.

	Travel **TO** work	Travel **FROM** work
Underground (Tube)	□	□
Train (Overground)	□	□
Bus, minibus or coach	□	□
Taxi	□	□
Motorcycle or moped	□	□
Driving a car or van	□	□
Passenger in a car or van	□	□
Bicycle	□	□
Walk	□	□
Jog	□	□
Other	□	□
Please specify	_____	

On the days that you will travel to work/your place of study in the week that starts tomorrow, how will you be travelling to and from work/your place of study? Tick all that apply.

	Travel **TO** study	Travel **FROM** study
Underground (Tube)	□	□
Train (Overground)	□	□
Bus, minibus or coach	□	□
Taxi	□	□
Motorcycle or moped	□	□
Driving a car or van	□	□
Passenger in a car or van	□	□
Bicycle	□	□
Walk	□	□
Jog	□	□
Other	□	□
Please specify	_____	

Is there a safe place to leave bicycles at your work/place of study?

Yes □
No □
Don't know □

Your household income

We would like to ask you about your household income from all sources and earnings after tax and other deductions (including any benefits). You can choose to answer this question in one of three ways: weekly, monthly, or yearly. Please indicate the easiest way for you to answer this question:

Weekly □
Monthly □
Yearly □
Don't know my household income □
Do not wish to answer □

How much is your household income approximately per week?

Less than £90 □
£90 to less than £200 □
£200 to less than £350 □
£350 to less than £600 □
£600 to less than £900 □
£900 or more □

How much is your household income approximately month?

Less than £390 □
£390 to less than £870 □
£870 to less than £1,500 □
£1,500 to less than £2,600 □
£2,600 to less than £3,900 □
£3,900 or more □

How much is your household income approximately per year?

- Less than £4,700 □
- £4,700 to less than £10,400 □
- £10,400 to less than £18,200 □
- £18,200 to less than £31,200 □
- £31,200 to less than £46,800 □
- £46,800 or more □

About Your Health

How is your health in general?

- Very good □
- Good □
- Fair □
- Bad □
- Very bad □

Do you have any particular problems with your health?

- Yes □
- No □

Please specify what the most important problem is (e.g. asthma)

_____

Are your day-to-day activities limited because of a health problem or disability which has lasted, or is expected to last, at least 12 months?

- Yes, limited a lot □
- Yes, limited a little □
- No □

Are you currently pregnant?

- Yes □
- No □

How far along in your pregnancy are you? You can answer in weeks or months.

- Weeks □
- Months □
- Unsure □

Under each heading, please tick ONE box that best describes your health TODAY

Mobility

- I have no problems in walking about □
- I have slight problems in walking about □
- I have moderate problems in walking about □
- I have severe problems in walking about □
- I am unable to walk about □

Self-care

- I have no problems washing or dressing myself □
- I have slight problems washing or dressing myself □
- I have moderate problems washing or dressing myself □
- I have severe problems washing or dressing myself □
- I am unable to wash or dress myself □

Usual Activities (e.g. work, study, housework, family or leisure activities)

- I have no problems doing my usual activities □
- I have slight problems doing my usual activities □
- I have moderate problems doing my usual activities □
- I have severe problems doing my usual activities □

Pain/Discomfort

- I have no pain or discomfort □
- I have slight pain or discomfort □
- I have moderate pain or discomfort □
- I have severe pain or discomfort □

Anxiety/Depression

- I am not anxious or depressed □
- I am slightly anxious or depressed □
- I am moderately anxious or depressed □
- I am severely anxious or depressed □

We would like to know how good or bad your health is TODAY. The following scale is numbered from 0-100 where 0 means the WORST health you can imagine, and 100 means the BEST health you can imagine. In the box below the scale, enter a number between 0 and 100 of how you would describe your health TODAY.

The worst health you can imagine										The best health you can imagine	Please indicate
0	10	20	30	40	50	60	70	80	90	100	_____

The following four questions ask about your feelings about aspects of your life. There are no right or wrong answers. For each of these questions, please give an answer on a scale of 1 to10.

Overall, how satisfied are you with your life nowadays?

1	2	3	4	5	6	7	8	9	10
Not at all									Completely

Overall, to what extent do you feel that the things you do in your life are worthwhile

1	2	3	4	5	6	7	8	9	10
Not at all									Completely

Overall, how happy did you feel YESTERDAY

1	2	3	4	5	6	7	8	9	10
Not at all									Completely

Overall how anxious did you feel YESTERDAY

1	2	3	4	5	6	7	8	9	10
Completely									Not at all

Some questions about how you have been feeling in the LAST WEEK.
For each item below, please tick the box to the response that comes closest to how you have been feeling over the last week. Don't take too long over the answers: your immediate reaction will probably be the most accurate.

I feel tense and 'wound up'	Most of the time	□
	A lot of the time	□
	From time to time, occasionally	□
	Not at all	□
I feel as if I am slowed down	Nearly all of the time	□
	Very often	□
	Sometimes	□
	Not at all	□
I still enjoy the things I used to enjoy	Definitely as much	□
	Not quite as much	□
	Only a little	□
	Hardly at all	□
I get a sort of frightened feeling like 'butterflies' in the stomach	Not at all	□
	Occasionally	□
	Quite often	□
	Very often	□
I get a sort of frightened feeling as if something awful is going to happen	Very definitely	□
	Yes, but not too badly	□
	A little, but it doesn't worry me	□
	Not at all	□

I have lost interest in my appearance	Definitely ☐ I don't take as much care as I should ☐ I might not take quite as much care ☐ I take just as much care ☐
I feel restless, as if I have to be on the move	Very much indeed ☐ Quite a lot ☐ Not very much ☐ Not at all ☐
Worrying thoughts go through my mind	A great deal of the time ☐ A lot of the time ☐ From time to time, but not too often ☐ Only occasionally ☐
I look forward with enjoyment to things	As much as I ever did ☐ Rather less than I used to ☐ Definitely less than I used to ☐ Hardly at all ☐
I feel cheerful	Not at all ☐ Not often ☐ Sometimes ☐ Most of the time ☐
I get sudden feelings of panic	Very often indeed ☐ Quite often ☐ Not very often ☐ Not at all ☐
I can sit at ease and feel relaxed	Definitely ☐ Usually ☐ Not often ☐ Not at all ☐
I can enjoy a good book or radio or TV programme	Often ☐ Sometimes ☐ Not often ☐ Very seldom ☐
I feel lonely	All of the time ☐ Often ☐ Sometimes ☐ Never ☐

Smoking

Do you currently smoke?	Yes ☐ No ☐

How many cigarettes do you smoke on average, in a day? _____

Drinking

Do you drink alcohol?	Yes ☐ No ☐

Which of the following do you USUALLY drink in an AVERAGE week?	Small glass of wine □ Standard glass of wine □ Large glass of wine □ Pint of beer □ Bottled beer □ Can of beer □ Alcopops □ Spirits □

How many small glasses of wine do you drink in an AVERAGE week?	____
How many standard glasses of wine do you drink in an AVERAGE week?	____
How many large glasses of wine do you drink in an AVERAGE week?	____
How many pints of beer do you drink in an AVERAGE week?	____
How many bottles of beer do you drink in an AVERAGE week?	____
How many cans of beer do you drink in an AVERAGE week?	____
How many bottles of alcopops do you drink in an AVERAGE week?	____
How many shots of spirits do you drink in an average week?	____

	Strongly agree	Agree	Neither agree nor disgaree	Disagreee	Strongly Disgaree
This area is a place I enjoy living in	□	□	□	□	□
This area has good local transport	□	□	□	□	□
This area has good leisure things for people like myself, leisure centres or community centres for example	□	□	□	□	□
Vandalism, graffiti or deliberate damage to property is a problem in my local area	□	□	□	□	□
My neighbourhood is generally free from litter	□	□	□	□	□
There is too much traffic in my neighbourhood	□	□	□	□	□
My neighbourhood is attractive to look at (e.g. there are attractive buildings, green space. landscaping views)	□	□	□	□	□
I enjoy walking in my neighbourhood	□	□	□	□	□

Safety in your neighbourhood	Strongly agree	Agree	Neither agree nor disgaree	Disagreee	Strongly Disgaree
There is a lot of crime in my neighbourhood	□	□	□	□	□
The level of crime in my neighbourhood makes it unsafe to walk on the streets during the day	□	□	□	□	□
The level of crime in my neighbourhood makes it unsafe to walk on the streets at night	□	□	□	□	□
There are threatening groups of young people in my neighbourhood	□	□	□	□	□
Our neighbourhood streets have good lighting at night	□	□	□	□	□
You often see people out on walks or riding their bicycles in my neighbourhood	□	□	□	□	□

People in your neighbourhood	Strongly agree	Agree	Neither agree nor disgaree	Disagreee	Strongly Disgaree
Most people in this neighbourhood can be trusted	□	□	□	□	□
Most people in this neighbourhood are friendly	□	□	□	□	□
People in this neighbourhood will take advantage of you	□	□	□	□	□

How many people are there in your neighbourhood with whom you exchange small favours (e.g. looking after parcels or keys)?

None □
1 person □
2 people □
3 people □
4 people or more □

How many of your neighbours do you know by name? (Include people in your neighbourhood)

None □
1 person □
2 people □
3 people □
4 people or more □

Stores, facilities and other things in your neighbourhood

About how long would it take to get from your home to the NEAREST business or facility listed below if you WALKED to them?

	1-5 min	6-10 min	11-20 min	21–30 min	More than 30 min	Don't know
Local shop: grocery shop, bakery, butcher etc	□	□	□	□	□	□
Supermarket	□	□	□	□	□	□
Local services such as a bank, post office or library	□	□	□	□	□	□
Restaurant, cafe, pub or bar	□	□	□	□	□	□
Fast-food restaurant or take-away	□	□	□	□	□	□
Bus stop, tube or train station	□	□	□	□	□	□
Sport and leisure facility such as swimming pool, sports field or fitness centre	□	□	□	□	□	□
Open recreation area such as a park or other open space	□	□	□	□	□	□
A place of worship	□	□	□	□	□	□

How often do you go to...

	Daily/ Almost daily	At least weekly	Less than weekly	Never
The local shop: grocery shop, bakery, butcher, etc	□	□	□	□
The supermarket	□	□	□	□
Local services such as bank, post office or library	□	□	□	□
The restaurant, cafe, pub or bar	□	□	□	□
The fast-food restaurant or take-away	□	□	□	□
The bus-stop, tube or train stop	□	□	□	□
The sport and leisure facility such as the swimming pool, sports field or fitness centre	□	□	□	□
The open recreation area such as a park or other open space	□	□	□	□
A place of worship	□	□	□	□

Do you USUALLY **WALK** or **CYCLE** to the local shop, grocery shop, bakery, butcher etc?	Yes □	No □
Do you USUALLY **WALK** or **CYCLE** the supermarket?	Yes □	No □
Do you USUALLY **WALK** or **CYCLE** to local services such as a bank, post office or library?	Yes □	No □
Do you USUALLY **WALK** or **CYCLE** to the restaurant, cafe, pub or bar?	Yes □	No □
Do you USUALLY **WALK** or **CYCLE** to the fast-food restaurant or take-away?	Yes □	No □
Do you USUALLY **WALK** or **CYCLE** to the bus stop, tube or train station?	Yes □	No □
Do you USUALLY **WALK** or **CYCLE** to the sport and leisure facility such as swimming pool, sports field or fitness centre?	Yes □	No □
Do you USUALLY **WALK** or **CYCLE** to an open recreation area such as a park or other open space?	Yes □	No □
Do you USUALLY **WALK** or **CYCLE** to your place of worship?	Yes □	No □

Physical Activity

This section is about the kinds of physical activities that people do as part of their everyday lives.

Were you sick or injured last week, or did anything stop you from doing your normal physical activities?	Yes □ No □
How do you get to your accommodation?	Mainly use the stairs □ Mainly use the lift □ A bit of both □ Not applicable (i.e. live on ground floor) □
Is there a bicycle in your household that you could ride if you wanted to?	Yes □ No □ Not sure □
Is it in a roadworthy condition?	Yes □ No □ Not sure □
When was the last time you rode a bicycle?	Within the last week □ Within the last month □ Within the last year □ More than one year ago □ Never □

Which of the following did you do LAST WEEK from (Monday-Sunday)

Went to a park, playground or playing field	Yes □	No □
Went to watch a sport	Yes □	No □
Went to the gym	Yes □	No □
Went swimming	Yes □	No □
Went cycling	Yes □	No □
Went jogging or running	Yes □	No □
Went walking for exercise	Yes □	No □
Took part in any other sporting activity	Yes □	No □

Which sporting activity did you do in the last week?
Tick all that apply.

Basketball □
Cricket □
Dance □
Football □
Gymnastics □
Ice-skating □
Martial Arts (e.g. karate) □
Rugby □
Skateboarding □
Tennis □
Yoga □
Other □

Please specify _____

The following questions will ask you about the time spent being vigorously and moderately active in the LAST 7 DAYS. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and garden work, to get from place to place and in your spare time for recreation, exercise or sport.

First, think about the VIGOROUS activities you did in the LAST 7 DAYS. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

During the last 7 days, on how many days did you do VIGOROUS physical activities like heavy lifting, digging, aerobics or fast bicycling?

None 1 2 3 4 5 6 7

How much time did you usually spend doing VIGOROUS physical activities on one of those days?

Hours per day _____ Minutes per day _____ Not sure □

Now think about the MODERATE activities that you did in the LAST 7 DAYS. Moderate activities refer to the activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

During the last 7 days, on how many days did you do MODERATE physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

None 1 2 3 4 5 6 7

During the last 7 days, on how many days did you do MODERATE physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

Hours per day _____ Minutes per day _____Not sure □

Think about the time you spent WALKING in the LAST 7 DAYS. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise or leisure.

During the last 7 days, on how many days did you WALK for at least 10 minutes at a time?

None 1 2 3 4 5 6 7

How much time did you usually spend WALKING on one of those days?

Hours per day _____ Minutes per day _____Not sure □

Think about the time you spent SITTING on weekdays during the last 7 days. Include any time spent at work, at home, whilst doing course work and during leisure time, This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television.

During the LAST 7 DAYS, how much time did you spend SITTING in total on a week day

Hours per day _____ Minutes per day _____Not sure □

Will your activities over the next seven days be typical for you? Yes □ No □

Costs of Undertaking Physical Activity

Some questions about money you may have spent to do physical activity

In the LAST 3 MONTHS, did you pay for any membership fees to do physical activity? Yes □ No □

How much did you spend? £ _____

Did you receive any vouchers/money off towards the cost? Yes □ No □

How much did you receive in this period (i.e. in the last 3 months)? £ _____

In the LAST 3 MONTHS, did you pay for any individual classes, entrance fees or groups to do physical activity (e.g. to go to a swimming pool, other sports facility)? (If not included in the membership fees in previous question). Yes □ No □

In the LAST 3 MONTHS, how many times did you go to any individual or group classes or pay entrance fees to do physical activity? _____

How much did you spend? £ _____

Did you receive any vouchers/money off towards the cost? Yes □ No □

How much did you receive in this period (i.e. in the last 3 months)? £ _____ _____

In the LAST 3 MONTHS, did you pay for shoes or clothing to do physical activity? Yes □ No □

In the LAST 3 MONTHS, how many pairs of shoes/items of clothing did you pay for? _____

How much did you spend? £ _____

Did you receive any vouchers/money off towards the cost? Yes □ No □

How much did you receive in this period (i.e. in the last 3 months)? £ _____

In the LAST 3 MONTHS, did you have to pay for equipment to do physical activity? Yes □ No □

In the LAST 3 MONTHS, how many items of equipment did you pay for? _____

How much did you spend? £ _____

Did you receive any vouchers/money off towards the cost? Yes □ No □

How much did you receive in this period (i.e. in the last 3 months)? £ _____

In the LAST 3 MONTHS, did you have to pay for childcare to enable you to do your physical activity? Yes □ No □

In the LAST 3 MONTHS, how many times did you pay for childcare to enable you to do your physical activity? _____
How much did you spend? £ _____
Did you receive any vouchers/money off towards the cost? Yes □ No □
How much did you receive in this period (i.e. in the last 3 months)? £ _____

In the LAST 3 MONTHS, did you have to pay for anything else to do physical activity? Yes □ No □
What else did you have to pay for?
_____
How much did you spend? £ _____
Did you receive any vouchers/money off towards the cost? Yes □ No □
How much did you receive in this period (i.e. in the last 3 months)? £ _____

Thinking about the last time you went to do physical activity, how long did it take you, in total, to travel TO and FROM the place where you went to do this activity? Hours _____ Minutes _____
How much did you spend? £ _____
Did you receive any vouchers/money off towards the cost? Yes □ No □
How much did you receive in this period (i.e. in the last 3 months)? £ _____

Some questions about your attitudes to exercise and health
This section asks for your personal opinions about exercise/physical activity. This includes things like walking, sports, running, swimming, cycling etc.

Please tick one box to indicate how strongly you agree or disagree with each statement

	Strongly agree	Agree	Neither agree nor disagree	Disagreee	Strongly Disgaree
Doing exercise is satisfying and rewarding for me	□	□	□	□	□
Doing exercise regularly is good for me	□	□	□	□	□
Exercising regularly can be helpful for my health	□	□	□	□	□
Exercising regularly can help me to get out of doors	□	□	□	□	□
Exercising regularly can help me control my weight or lose weight	□	□	□	□	□

Your belief in your ability to exercise
How sure are you that you would do each of the following:

	Very sure	Pretty sure	A little sure	Not at all sure
Exercise regularly (3 times a week for 20 minutes)	□	□	□	□
Exercise when you are feeling tired	□	□	□	□
Exercise when you are feeling under pressure to get things done	□	□	□	□
Exercise when you are feeling down and depressed	□	□	□	□
Exercise when you have too much work to do	□	□	□	□
Exercise when there are other more interesting things to do	□	□	□	□
Exercise when your family or friends do not provide any support	□	□	□	□
Exercise when you really don't feel like it	□	□	□	□
Exercise when you are away from home (e.g. visiting, on holiday)	□	□	□	□

In the LAST MONTH, how often did you:

	Daily/ Almost daily	At least weekly	At least 2-3 times a week	At least monthly	Less than monthly/ Never
Set a goal for how much walking you would like to do	□	□	□	□	□
Plan particular days or times when you would walk	□	□	□	□	□
Walk with someone in your neighbourhood	□	□	□	□	□
Walk with your dog in your neighbourhood	□	□	□	□	□
Set a goal for how much physical activity you would like to do	□	□	□	□	□
Plan particular days or times when you would be physically active	□	□	□	□	□
Do physical activity with someone in your neighbourhood	□	□	□	□	□

Social support and physical activity

In the last month, how often did the following people do physical activity, including walking, WITH YOU?

	Daily/ Almost daily	At least weekly	At least 2-3 times a week	At least monthly	Less than monthly/ Never
Your spouse/partner	□	□	□	□	□
Close family members	□	□	□	□	□
People at work	□	□	□	□	□
Close friends	□	□	□	□	□
Your neighbours or other people in your neighbourhood	□	□	□	□	□

Television / Video / DVD / PC

How many hours on a WEEK DAY do you USUALLY spend watching television, videos or DVDs?

None □
1 hour or less □
1-2 hours □
2-3 hours □
3-4 hours □
4-6 hours □
6-8 hours □
8-10 hours □
11 hours or more □

How many hours on a WEEKEND DAY (Saturday OR Sunday) do you USUALLY spend watching television, videos or DVDs?

None □
1 hour or less □
1-2 hours □
2-3 hours □
3-4 hours □
4-6 hours □
6-8 hours □
8-10 hours □
11 hours or more □

How many hours on a WEEK DAY do you USUALLY spend playing physically active computer games (e.g. Wii Sport)?

None □
1 hour or less □
1-2 hours □
2-3 hours □
3-4 hours □
4-6 hours □

	6-8 hours □ 8-10 hours □ 11 hours or more □
How many hours on a WEEKEND DAY (Saturday OR Sunday) do you USUALLY spend playing physically active computer games (e.g. Wii Sport)?	None □ 1 hour or less □ 1-2 hours □ 2-3 hours □ 3-4 hours □ 4-6 hours □ 6-8 hours □ 8-10 hours □ 11 hours or more □
How many hours on a WEEK DAY do you USUALLY spend playing other computer games (e.g. X-Box, PlayStation)?	None □ 1 hour or less □ 1-2 hours □ 2-3 hours □ 3-4 hours □ 4-6 hours □ 6-8 hours □ 8-10 hours □ 11 hours or more □
How many hours on a WEEKEND DAY (Saturday OR Sunday) do you USUALLY spend playing other computer games (e.g. X-Box, PlayStation)?	None □ 1 hour or less □ 1-2 hours □ 2-3 hours □ 3-4 hours □ 4-6 hours □ 6-8 hours □ 8-10 hours □ 11 hours or more □
Do you have a TV in your bedroom?	Yes □ No □
Do you have a PC/laptop in your bedroom?	Yes □ No □
Do you USUALLY watch TV in your bedroom (this can include a computer where you can watch 'catch-up' TV, DVDs or download films)?	Yes □ No □
How many hours on a WEEK DAY do you USUALLY spend on a PC/laptop for work or study time only?	None □ 1 hour or less □ 1-2 hours □ 2-3 hours □ 3-4 hours □ 4-6 hours □ 6-8 hours □ 8-10 hours □ 11 hours or more □
How many hours on a WEEKEND DAY (Saturday OR Sunday) do you USUALLY spend on a PC/laptop for work or study time only?	None □ 1 hour or less □ 1-2 hours □ 2-3 hours □ 3-4 hours □ 4-6 hours □ 6-8 hours □ 8-10 hours □ 11 hours or more □

Your Eating Habits

FRUIT (fresh, frozen or tinned)

Please tell us how many portions of fruit (for example, an apple, an orange, some grapes) you USUALLY eat in a day (include fresh, frozen or tinned)	I never have fruit □ I have fruit some days but not every day □ One portion a day □ Two portions a day □ Three portions a day □ Four portions a day □

VEGETABLES (fresh, frozen or tinned)

Please tell us how many times you USUALLY eat vegetables or salad, either on their own or with other food in a day. DO NOT include potatoes or chips.	I never have vegetables or salad □ I have vegetables and salad some days but not every day □ One portion a day □ Two portions a day □ Three portions a day □ Four portions a day □

Do you USUALLY eat breakfast? Yes □ No □

Do you USUALLY eat a meal at home watching television?
Yes, everyday □
Yes, most days □
Yes, sometimes □
No, not usually □

Do you USUALLY eat at least one meal at home as a family?
Yes, everyday □
Yes, most days □
Yes, sometimes □
No, not usually □

Your Sleeping Habits (Please specify am or pm if using 12 hour format)

What time do you **USUALLY** get up in the morning on a **WEEK DAY?**
(For example, enter as 7am or 7:30am or 07:30) _____
What time do you **USUALLY** go to sleep on a **WEEK DAY?**
(For example, enter as 11pm, 11:00pm or 23:00) _____
What time do you **USUALLY** get up in the morning on a **WEEKEND DAY?**
(For example, enter as 8am, 8:00pm or 08:00) _____
What time do you **USUALLY** go to sleep on a **WEEKEND DAY?**
(For example, enter as 12pm, 12:00pm or 00:00) _____

SECTION C: PARENT QUESTIONS

About your children

Do you have a child or children at primary school? Yes □ No □
Do you have a child or children at secondary school? Yes □ No □

Your Child(ren)'s School and Travel
The following questions are asked in relation to your child at primary and/or secondary school.

Would it be difficult for your primary school child/ren to WALK or RIDE A BICYCLE to school? Yes □ No □
Would it be difficult for your secondary school child/ren to WALK or RIDE A BICYCLE to school? Yes □ No □

Is this because: (please tick all that apply in the relevant column)	Primary School Child	Secondary School Child
There are not enough footpaths	☐	☐
The school is too far away	☐	☐
Other commitments don't allow it	☐	☐
My child has a lot to carry	☐	☐
My child does not know the way to school	☐	☐
My child has commitments before school	☐	☐
My child has commitments after school	☐	☐
It is more convenient for me to drive my child to school on the way to somewhere else	☐	☐
My child would have to cross a busy road	☐	☐
There are no safe crossings for my child to use	☐	☐
There is a lot of traffic near the school	☐	☐
Other	☐	☐

Please specify _____

Children and the Local Neighbourhood	Strongly agree	Agree	Neither agree nor disgaree	Disagreee	Strongly Disgaree
There are many places for children to go (alone or with someone) within easy walking distance of my home					
Primary school child	☐	☐	☐	☐	☐
Secondary school child	☐	☐	☐	☐	☐
From my home, it is easy for children to walk to public transport (bus, tube, train) alone or with someone					
Primary school child	☐	☐	☐	☐	☐
Secondary school child	☐	☐	☐	☐	☐
There are major barriers to walking in our local area that make it hard for children to get from place to place (for example, major roads, railway lines, rivers)					
Primary school child	☐	☐	☐	☐	☐
Secondary school child	☐	☐	☐	☐	☐

Do you agree or disagree with the following statements:

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
There is too much traffic for children to walk safely in our neighbourhood	☐	☐	☐	☐	☐
Children would have to cross a busy road to walk or ride a bicycle to reach the local shops	☐	☐	☐	☐	☐
Children would have to cross a busy road to walk or ride a bicycle to reach the local park	☐	☐	☐	☐	☐
Children would need to cross a busy road to catch a bus or train	☐	☐	☐	☐	☐
There are no safe crossings for children to use if he/she walked or cycled to the local shop	☐	☐	☐	☐	☐
There are no safe crossings for children to use if he/she walked or cycled to reach the local park	☐	☐	☐	☐	☐

Concerns about Crime and Strangers in the Local Neighbourhood

The crime rate in my neighbourhood makes it unsafe for a child to go on walks alone or with someone during the day	☐	☐	☐	☐	☐

The crime rate in my neighbourhood makes it unsafe for a child to go on walks alone or with someone at night	□	□	□	□	□
I am worried about letting a child play or walk alone or with someone in my neighbourhood	□	□	□	□	□
I would be concerned to let a child outside because of the presence of strangers	□	□	□	□	□

TV and Computer Games

In general, how often do you (and/or your partner) restrict your child/children in the following activities:

	Daily/ Almost daily	At least weekly	At least 2-3 times a week	At least monthly	Less than monthly / Never
Watching TV/Video/DVD					
Primary school child	□	□	□	□	□
Secondary aged child	□	□	□	□	□
Using a computer					
Primary school child	□	□	□	□	□
Secondary aged child	□	□	□	□	□
Playing non-physically active computer games (e.g. X-Box, PlayStation)					
Primary school child	□	□	□	□	□
Secondary aged child	□	□	□	□	□
Playing physically active computer games (e.g. Wii Sports)					
Primary school child	□	□	□	□	□
Secondary aged child	□	□	□	□	□

In general, how often do you (and/or your partner) allow your child/children to:

	Never	Rarely	Sometimes	Often	Very often
Play outside anywhere in the neighbourhood					
Primary school child	□	□	□	□	□
Secondary aged child	□	□	□	□	□
Walk or cycle to a friend's house					
Primary school child	□	□	□	□	□
Secondary aged child	□	□	□	□	□

During a typical week, how often do you (and/or your partner):

Encourage your child/children to do a physical activity or play sports					
Primary school child	□	□	□	□	□
Secondary aged child	□	□	□	□	□
Do a physical activity or play sports with your child/children					
Primary school child	□	□	□	□	□
Secondary aged child	□	□	□	□	□
Take your child/children to a place where they can do physical activities or play sports					
Primary school child	□	□	□	□	□
Secondary aged child	□	□	□	□	□
How often do you watch your child/children participate in a physical activity or sport					
Primary school child	□	□	□	□	□
Secondary aged child	□	□	□	□	□
Tell your child/children that physical activity is good for his or her health					
Primary school child	□	□	□	□	□
Secondary aged child	□	□	□	□	□

SECTION D: FIELDWORK RESEARCHER

Is there anything else you would briefly like to tell us about where you live and taking part in the ENABLE London study?

Please check if participant contact details are correct. Enter any changes to address details here:

Are telephone numbers correct? Check home and mobile number. Enter any changes here:

Is the email address correct? If not, enter correctly:

Partner's mobile number (if applicable):

We will be following up some families in a year from now so that we are able to compare activities over the course of a year of those who move and do not move into new housing. The visit will be the same as what I have done today, an interview and issuing you with devices to wear for a week and then coming back to collect them. Would you be happy for us to contact you a year from now? By saying yes, you are agreeing for us to contact you and you would still be free to withdraw.

Yes □ No □

If for any reason we are unable to contact you in a year's time, is there someone we can use as a second contact? We will only contact them if we are unable to get hold of you. (FW: Please specify name of 2nd contact and their relationship to main adult. If possible, ask for address, home and mobile numbers).

Referral recruitment

And finally, we are recruiting families into the study and wondered whether you know anyone, similar to yourself, i.e. from a similar household, who may be willing to be contacted to take part in the study (they don't have to be moving to East Village)? I can take their details today, or if you would like to speak with them first, I can leave you with some forms. Please include these in the envelope when you return your belt. For anyone you recommend and we visit, you will receive a shopping voucher.

ADDITIONAL QUESTIONS ADDED TO THE FOLLOW-UP QUESTIONNAIRE

Have you ever lived in East Village? Yes □ No □

[If yes] Which month did you moved to East Village? _____

Which year did you move into East Village? _____

Which month did you move out of East Village? _____

Which year did you move out of East Village? _____

How often do you visit Westfield, Stratford City?

Everyday □
Once a week □
2-3 times a month □
Once a month □
Less than once a month □
Never visited it □

How often do you do the following activities when you visit Westfield, Strtaford City? Tick all that apply.	Always	Usually	Sometimes	Never
Shopping	□	□	□	□
Cinema or bowling	□	□	□	□

Eating out	□	□	□	□
Meeting friends	□	□	□	□

Do you do any other activity when you visit Westfield, Stratford City Yes □ No □
[If yes} Please specify what the other activity is _____

How often do you do this other activity when you visit Westfield, Stratford City?	Always	Usually	Sometimes	Never
	□	□	□	□

How often do you visit the Olympic Park?

Everyday □
Once a week □
2-3 times a month □
Once a month □
Less than once a month □
Never visited it □

How often do you do the following activities when you visit the Olympic Park? Tick all that apply.	Always	Usually	Sometimes	Never
Walking	□	□	□	□
Cycling	□	□	□	□
Play sports	□	□	□	□
Meeting friends	□	□	□	□

Do you do any other activity when you visit the Olympic Park? Yes □ No □
[If yes} Please specify what the other activity is _____

Appendix 2 ENABLE London semistructured interview schedule

1: Dictaphone 2: maps 3: vouchers 4: highlighter pens
Preamble:
Focus on: physical Environment and Travel
Hello, thank you for taking part etc…
We are talking to some of the residents who were involved with the ENABLE London project to find out more about how people travel around. We are interested in how you travelled around in the area you moved from and also how you travel around the area you live in now and what might be different. Although we know you have helped us with lots of measurements in ENABLE it's really helpful for us to hear from you about some of the things we can't easily measure. We'd like to talk to you about how you travel as well as what sort of places you go to and what might help you or make it more difficult to visit places
There are no right or wrong answers, please tell as much or as little as you like or decide not to answer any question.
It will take 45 mins
We'll be recording
There will be maps
Researcher: Let me tell you a bit more about me – I'm a researcher…..
What about you?
What do you call this area?
Have you lived here long?
Where did you live before?
Do you live on your own?.....
Is it near work?....
What did you know about it before you moved here?
… more of this later!

Section 1: Old vs new neighbourhood

- *Why were you interested in moving to this area?*
- *What attracted to you to this area…. This specific area particularly?*
  (If reasons given are not related to environment (eg cost, commute, my mum lives there etc) prompt for environmental aspects if possible). Prompt – was there anything particular about the way the neighbourhood looked that was part of your decision?
- *Why did you want to move away from where you lived before?*
  (Reasons for moving, main benefits/limitations for old vs new neighbourhood)
- *Is it different from what you expected it to be? In what way?*
- *Do you miss anything from where you used to live?*
- *Do you go back there? How often? What sort of things do you go back for?*
  (Expectations, connection to old neighbourhood)
- *What do you think are the main differences in the way the neighbourhood looks? physical environment here compared to where you used to live?*
  Then prompt: public transport / walk ways / cycle ways / cycle storage / restricted parking?
  Also: safety / attractiveness / lighting / distance to amenities (shops/leisure/GP etc)
- *Are there more or less people around and out-and-about? (Prompt for walking/cycling)*
- *How does it compare to the old area*
- *Does it feel more or less sociable and friendly? Why do you think that?*

Section 2: Travel and destinations in old vs new neighbourhood (use map 1)
We're interested in how you get around where you live now compared to where you used to live:

- *Let's start with **shopping!***
- *Can you tell me about where you shop now – 'everyday' shopping, weekly shop, non-food shopping*
  ('Where' as in type and location of shops - rather than specific stores)
- *Does how you get there influence where you go, how often, what you buy? E.g. you just talked about xxxxx. What other places could you go to…. Why this one?*
- *What would make it easier for you to do your shopping??*
- *Do you wish any different types of shop were available?*
- *If so where do you think they should be?*
- *Does it depend how much time you have – e.g. Is this different on weekdays and weekend?*
- *Now – how about where you used to shop before you moved. Was it any different? In what way?*

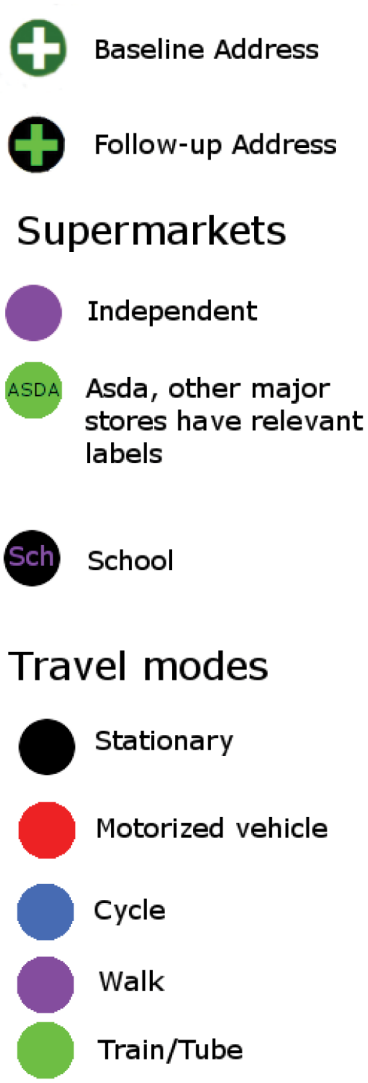
Repeat above for work? If they work
Then -what about other journeys that you make?
Visiting or helping friends and family/
eating out
leisure (outdoor and indoor)

prompt – need to define leisure – prompt for active leisure??
necessary appointments (e.g. medical)
place of worship

Section 3: General change in travel patterns (maps of before and after) (use map 2)
You may remember you kindly wore monitors around your waist as part of ENABLE. One of the ways we use this information is to look at travel patterns. Looking at these maps - How you move around seems to have changed since you moved ?
- explain maps etc.
- there seems to be more of …… this type of journey (walking, cycling, car, bus etc.) – small scale example – why do you think that is? Does it depend on day of the week? (prompt weekday vs weekend). Do you think it's different to the maps most days? In what way?
You seem to make different journeys at the weekends….

Section 4 (optional) (use map 3)
This map shows places you spend time in. It looks like you do/don't spend time where you used to live, why's that?

Legend for maps (note, maps are not shown due to participant confidentiality issues)



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